Building and Environment 105 (2016) 104–115

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Avoiding mould growth in an interiorly insulated log wall

Üllar Alev*, Targo Kalamees

Department of Structural Design, Tallinn University of Technology, Tallinn, 19086, Estonia

ARTICLE INFO

Article history:
Received 19 February 2016
Received in revised form
16 May 2016
Accepted 17 May 2016
Available online 19 May 2016

Keywords:
Hygrothermal performance
Interior thermal insulation
Log wall
Moisture safety
Mould growth risk

ABSTRACT

Interior thermal insulation in a cold climate is risky from a hygrothermal point of view. Designers and customers are looking for solutions that provide a moisture-safe design. Avoiding mould growth in wall structures is the primary design criterion when planning to add interior insulation to a log wall. In this study indoor humidity load, average indoor temperature, the thickness of a log wall and additional insulation layer, the initial moisture content of logs and the vapour diffusion thickness of a vapour barrier were varied and mould growth risk was identified. In general, our results showed that a water vapour barrier with an equivalent vapour diffusion thickness of 2 m or more is acceptable when indoor moisture excess is up to 5 g/m^3 during winter. In these conditions, the maximum measured moisture content of logs before insulation should be below 12% and the thickness of interior insulation of mineral wool can be up to 50 mm. The water vapour resistance of a vapour barrier depends on the use of the house (for general living or as a summer cottage) and indoor humidity load. It is necessary to install a vapour barrier covering interior insulation carefully to avoid air leakages through it. If an improved vapour barrier and decreased indoor moisture excess are used, then the thermal resistance of an additional internal insulation layer can be more than double of the thermal resistance of the log wall before adding the insulation, otherwise both thermal resistances should be equal.

1. Introduction

Log houses of different sizes were common in the Baltic and Nordic countries a century ago. Often these old log houses are still in use. Now, log houses are gaining popularity because of low embodied energy, and they are still a usable building type. Designers and owners of wooden log houses need correct insulation solutions to improve the energy efficiency and thermal comfort of their houses. A need for additional interior insulation exists in old houses when a house is a cultural heritage monument or is located in an area where it is required to preserve the exterior appearance of the house. When an architect or the owner of a new log house wants to expose the natural surface of a log wall on the exterior side, a solution to consider might be interior insulation. This solution may be also used in apartment buildings, built of wooden logs, if only a few owners want or can carry out deep renovation with additional thermal insulation. In such cases, an insulation layer from the inside room by room is an easy solution that is the most appealing one visually.

In addition to traditional mineral wool insulation, there also exist other materials used for interior thermal insulation: calcium silicate board [1], polyisocyanurate board [2,3], perlite-based board [4], wood fibre board [5], expanded polystyrene [6,7], aerogel [8], vacuum insulation panels (VIP) [9], and hydrophilic mineral wool [10]. Materials may be grouped by hygrothermal performance as vapour-tight or open to water vapour diffusion, capillary active or non-capillary active. All these properties strongly affect the performance of interior insulation. Vereecken and Roels [11] have compared the hygric performance of massive masonry walls provided with capillary active as well as more standard non-capillary active insulation systems and showed that stored moisture inside walls with a capillary active system is higher than for walls with a traditional vapour-tight system. Guizzardi [12] has evaluated the use of insulating aerogel plaster as an interior insulation layer on a masonry wall with a façade worth preserving. Based on her simulations, walls with internal aerogel plaster show a hygrothermal behaviour that is similar to the behaviour of walls retrofitted with other vapour insulation materials, such as calcium silicate, but have better thermal insulation efficiency.

Interior thermal insulation in a cold climate is risky from a moisture safety point of view. In general, the risk of failure will be higher if thicker interior insulation layers are used. The risk of

* Corresponding author.
E-mail address: ullar.alev@ttu.ee (Alev).

http://dx.doi.org/10.1016/j.buildenv.2016.05.020
0360-1323/

interior insulation failure means possible mould growth in the wall structure, spread of mould spores, moisture accumulation or water vapour condensation. Spores in indoor air may cause health problems for inhabitants.

Ibrahim et al. [14] have shown that interior thermal insulation systems can cause several moisture problems: inability to dry out over the years, condensation risk, etc. Pasek and Kesl [13] have shown that the interior insulation of the perimeter building envelope in the climatic conditions of Central Europe is quite unsuitable because of a high probability of damage to the structural system of the building compared to other possible varieties of perimeter wall designs. Pašek has also shown that stress increases in external walls and adjacent structures caused by non-forced effects of temperature changes in the environment after the application of internal insulation [17]. Bjarløv et al. [15] and Finken et al. [16] have shown problems with interior insulation in masonry walls without any additional driving rain protection.

A lot of the latest research is concentrated on the hygrothermal performance of wooden beam ends in an internally insulated masonry wall. Guizzardi et al. [18] have shown that an interior insulation layer results in higher damage risk compared to a non-insulated wall, and in case of internally insulated masonry walls with timber beams, exterior render properties have the biggest effect on the risk of damage to a wall (more so than the choice of the interior insulation material). Johansson et al. have investigated the hygrothermal performance of a brick wall with wooden beam ends after its insulation on the inside with VIPs [19] and have shown reduced temperatures and higher relative humidity in wooden beams after the addition of VIPs [9]. Harrestrup and Svendsen [20] have investigated the risk of mould growth in wooden beams and in the interface between interior insulation and a brick wall in case of various insulation strategies and have recommended that internal insulation not be applied on north-orientated walls since drying potential is reduced, while for a wall facing west, a solution with a gap above or below the floor/ceiling seemed to be moisture-safe. Also Morelli and Svendsen [21] have shown that the risk to incurring moisture problems at wooden beam ends can be resolved by not insulating the portion of the wall directly above or below the floor division.

Most of the above studies investigated the options and limits in the use of interior thermal insulation for improving the thermal resistance of old external walls made of stone. Wooden structures have been investigated much less. Ojanen [22] has studied interior insulation using a theoretical calculation model and assumed that a log wall is completely airtight; however, vertical air channels between the log and the insulation layer were suggested to reduce moisture levels. Arumägi and Kalamees [23] and Alev et al. [24] have measured old log walls with a high leakage rate and created a respective calculation model. Arumägi and Kalamees [23] measured a house with a high indoor moisture load, whereas Alev et al. [24] measured one with almost no indoor moisture load. Other differences between the above studies include the type and use of a house, the insulation materials employed, hygrothermal loads etc. In a new log house built specially for testing, three different interior insulation solutions were measured and compared [25]. Mineral wool 50 mm thick and an insulation layer of cellulose fibre performed similarly, but cellulose fibre needs at least a week to dry out before being covered with a vapour barrier. It is safe to install a reed mat layer up to 70 mm thick, and a reed mat with clay plaster allows construction moisture to dry out faster. Alev et al. [25] have concluded that when choosing a vapour barrier, calculations must be made for every case and that the choice depends on the use of the house and the indoor humidity load. The energy efficiency and hygrothermal properties (including RH between a load bearing structure and insulation, among other properties) of different small test buildings, including an interiorly insulated log building, have been compared by Jakovics et al. [26]. In the same small test buildings, air tightness and air exchange rates have been measured: a log house has higher air leakage rates compared to other structure types measured [27].

Hygrothermal simulation models have been well developed during the past decade and allow an assessment of hygrothermal performance in a building envelope quite accurately. This allows the use of a stochastic simulation method developed in IEA-EBC Project RAP-RETRO [28] to evaluate and optimize retrofitting measures, including energy efficiency, life cycle costs and durability. Vereecken et al. [29] have developed a decision tool based on a Monte Carlo analysis and have shown, however, that in case of buildings sensitive to frost damage or if there are wooden beam ends capillary active systems are shifted forwards and that vapour-tight systems tend to be preferable for structures resistant to frost damage. The effect of material properties [30] or the effect of one section of a wall assembly [31] on hygrothermal performance and the performance of interior insulation [32] have been analysed using a stochastic approach. Arumägi et al. [33] have analysed the reliability of 50 mm thick interior insulation in a 145 mm thick log wall in typical indoor and outdoor climatic conditions in Estonia. Based on these stochastic calculations, at a safety margin set at the lower 0.95 confidence level, the statistical probability of mould growth is 37%.

As outlined above, interior insulation is more complex and not as hygrothermally safe as the widely used exterior insulation. Increasing the thickness of an insulation layer leads to a decrease in heat loss through the external wall. Thus, it is necessary to find a solution where both the risk of failure and heat loss through walls are minimal. A designer needs knowledge about the maximum thickness of an insulation layer and a list of other materials required. A builder needs knowledge about appropriate building technology and the time-scale for insulation works. The aim of the present study was to identify hydrothermally functioning combinations by varying the main parameters affecting the hygrothermal performance of an interiorly insulated log wall.

2. Methods

2.1. Studied wall

There are many parameters affecting the hygrothermal performance of interior insulation: thickness of an insulation layer, thickness of a log wall, air leakage rate of a log wall, indoor and outdoor climate parameters like temperature, relative humidity (*RH*) and moisture excess, water vapour transmittance of wall layers, and initial moisture content (*MC*) of logs. Main characteristics of the calculation model used in this study are shown in Fig. 1 and material properties in Table 1. The critical surface (Fig. 1) in the wall in terms of moisture safety was the interior surface of the log wall in direct contact with the insulation layer. The affecting finishing layer was always gypsum board. The air and vapour barrier provided airtightness for the wall.

The wall was considered airtight in the calculation model because it turned out during model validation that it was more critical when air leakage was excluded from the calculation model, because average RH on the critical surface was slightly over 1% higher when there was no air leakage in the model (shown in Fig. 4, the line marked with an asterisk). In practice, it is possible to considerably decrease air leakage through a log wall by using modern sealing materials and methods.

An Estonian moisture test reference year [34], critical in terms of mould growth in Estonia, was used for the outdoor climate after a validation of the model with the measured outdoor climate.