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Hygrothermal Performance of Highly Insulated Timber-frame External Wall

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Abstract

The nearly zero energy buildings (nZEB) ideology foresees first and foremost that heat losses should be reduced remarkably compared to the present levels. The European Union has adopted an ambitious vision for the energy efficiency of its buildings and by the end of 2020 all new buildings must meet nZEB requirements. The efficient way to meet these requirements is to design and build passive, nZEB, highly insulated buildings.

This paper presents the outcomes of analysis of the hygrothermal performance of the highly insulated building envelope of the detached house, built in Estonia. The results indicated that the dry-out period of constructional moisture is directly dependent on initial moisture content of materials in structure and a higher risk was detected if vapor permeability of outer layers in the envelope is low. Also critical aspects of moisture performance change due to the modifications of designed materials in construction process without preliminary analysis are described. Thermal resistance of the wind barrier and water vapor permeability of the vapor barrier, also moisture capacity of insulation layer had the strongest influence on the relative humidity and hence, to mould growth risk in the critical point of highly insulated timber-frame external wall, between the insulation and the wind barrier surface.

In the design of highly insulated timber-frame walls more attention should be paid to the hygrothermal performance and moisture safety analysis. As a result of this study, some of the functional solutions of timber-frame external walls are described in this paper.

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Keywords: modular prefabricated elements, nZEB, hygrothermal performance, moisture safety;

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1. Introduction

Europe has adopted an ambitious vision for the energy efficiency of its buildings and by the end of 2020 all new buildings in the EU must meet nearly zero-energy building (nZEB) requirements.

In line with the EU directive[1], the new Estonian energy performance regulations came into force on July 2015 [2], establishing stricter primary energy use requirements for nZEB, low-energy, new and renovated buildings in Estonia. In addition to national requirements, there are several internationally recognized energy-performance levels implemented. The Passive House (PH) standard [3] is a widely known energy performance standard, which requires minimized energy demand for space heating and therefore thick insulation, absence of thermal bridges, air tightness, efficient windows and heat recovery ventilation.

Already some buildings have been designed and built in past few years in Estonia according to nZEB requirements and PH standards. The Palamuse and Valga municipalities made first steps toward PH already in 2009 in Estonia [4]. The first nZEB and certified PH in Estonia is a detached house located in Põlva that achieved the annual basis “plus-energy” building classification in the Estonian legislation. Estonian factory-built wooden houses have become nZEB and passive houses also are exported to many countries like Finland, Norway, Germany.

Construction Products Regulation [5] sets essential requirements for safety of buildings and other construction works but also to health, durability, energy economy, protection of the environment, economic aspects and other important parts in the public interest. A large number of moisture-related building problems such as mould growth and chemical emissions from decomposed material subjected to high moisture levels, have occurred during the last few years with adverse effects on health, building costs and confidence in the building industry [6]. The first year measurements of the PH in Estonia showed that absence of rain protection of structures, no moisture safety protocol during the construction period as well the high diffusion resistance of the wood fiber sheathing board outside the insulation increased humidity conditions in the externally insulated cross-laminated timber (CLT) panels over the critical level [7]. Hagerstedt and Harderup [8] have brought out the changes in moisture performance because of the modified solution in construction process. Many researchers have shown that increased insulation thicknesses may cause an increase in humidity levels and thereby increased risk of mould growth. Therefore, it is necessary to pay special attention to the hygrothermal performance and moisture safety of highly insulated constructions.

In this study, the hygrothermal performance of timber-frame walls of a detached house, designed to be PH, in Estonia was analyzed. The field measurements during the first two years after construction [9] showed exceeding of mould growth risk level in external walls and relatively high indoor moisture excess. In current study results of measurements and simulations were evaluated for designing highly insulated buildings.

2. Methods

2.1. Description of the constructions

The analyzed detached house, built in 2013, was designed according to PH principles. It has compact design, well insulated airtight structures and efficient service systems which lead to the low energy house classification according to Estonian legislation. External walls are made of composite beams and columns, consisting pinewood and oriented strand board (OSB) with step 625 mm and where cellulose insulation thickness is 500 mm. The interior side of beams was covered with 22 mm finished OSB that gave airtightness and stability of structures. Combinations of 24 mm soft fibreboard and/or 30 mm high density mineral wool slab were used as a wind barrier under finishing rain screen, wooden siding and/or plastered hardboard. The airtightness of the external envelope of the whole building q_{50}=0.3 $m^3/(h{\cdot}m^2)$. With different combinations of wind barrier and vapor barrier, three types of walls were built for further monitoring (see Fig. 1 below right, wall types 1, 2 and 3), where thermal transmittance U=0.10-0.11 $W/(m^2{\cdot}K)$. Wall type 1 was made to study the influence of PE vapor barrier. Wall type 3, where 24 mm soft fibreboard as wind barrier was intended to use, was initial design solution from architect. That solution was improved by adding 30 mm high density mineral wool slab onto the soft fibreboard in the last stage of design (wall type 2).