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Hygro-thermal and Mould Growth Risk Analysis of Common Foundation Structures

Filip Fedorik[a]*, Antti Haapala[b]

[a]*Structural Engineering and Construction Technology, University of Oulu, PO Box 4200, FI-90014 Oulu, Finland*
[b]*Wood Material Science, University of Eastern Finland, PO Box 111, FI-80101 Joensuu, Finland*

Abstract

The presented analysis deals with hygro-thermal numerical simulation and mould growth risk evaluation in cases representing common foundation structures of timber-framed houses in Finland. Three different structural approaches are addressed with estimation of potentially problematic elements during the building's life cycle that may require special caution in design process. The studied cases include common building materials such as mineral wool, timber, bricks, concrete, EPS, and so on, and the key differences consist of building element configurations. The selected application for mould growth analysis predicts growth initiation and/or its stage in given climate conditions. The size of structural elements and their placement have a significant impact on hygro-thermal performance of a structure, and hence likely on the health of its indoor environment and the sustainability of the building too.

Hygro-thermal analyses apply official weather data measured in Oulu region in Finland from 2009 to 2015 representing humid coastal conditions. The long-term analysis depicts hygro-thermal conditions inside the structure and on its layered interfaces and predicts mould growth initiation in selected positions. The numerical simulation indicates that applying less sensitive structural material on top of a building skin to protect timber-frame from humid external conditions would be beneficial. The conditions in wooden elements cause issues at a certain range of thermal conditions and sufficient exposure time. The study highlights problems that may occur in the ambient of foundation structures of common timber-framed houses.

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Keywords: hygro-thermal analysis; numerical simulation; mould index; timber-frame; foundation

* Corresponding author. Tel.: +35-844-910-7107.
E-mail address: filip.fedorik@oulu.fi

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1. Introduction

Hygro-thermal conditions represent some of the key factors to assure the sustainability of buildings. A risk associated with constant high humidity and liquid water inside structural elements is potentially increased in highly insulated airtight buildings [1]. As most of the recently designed buildings promise sustainability and low-energy consumption of living, they also feature a marginal risk based on subtle errors made during the construction procedure [2]. The future trend in building control is to emphasize the energy efficiency of buildings and this may cause some problems in current house designs modified to fulfil the energy standards.

Certain details of buildings are more sensitive to unfavourable hygro-thermal conditions than others, such as attics, junctions, windows, doors, foundations, and so on. Thermal bridges usually characterize these details. The heat flow is disrupted when compared to the ambient areas, hence rapid temperature change in short distance may occur and via certain hygro-thermal conditions, condensation of humidity may be initiated which, in turn, can lead to sufficient humidity to support mould growth. Consistently elevated humidity in combination of certain range of temperature and exposure time represents favourable conditions for biological growth of moulds [3-5]. If these conditions persist, sensitive materials may rot and markedly degrade the structural features. Brief wetting does not cause long-term issues in case the humidity can escape the structures – however, persisting water vapour can be detrimental.

The aim of the presented study is to simulate hygro-thermal conditions inside three common foundation structures applied in residential buildings in Finland (Fig 1). Concrete foundation supports the timber frame in all cases. Conditions near the bottom of envelope structure are of special interest. Additionally, the Mould Index methodology describing potential of growth on building material surface is applied. The mathematical model was developed by VTT Technical Research Centre of Finland and Tampere University of Technology based on long-term laboratory and on-site tests [3;4].

2. Analysed structures

The structures are represented by foundations of common timber-framed houses. Their differences consist mainly in envelope structure, where structural elements are of different thicknesses and order. The analysed cases studied within the presented paper are illustrated in the Fig. 1 together with monitored points. The hygro-thermal conditions are simulated in locations characterized by the presence of sensitive materials, between structural elements of different materials and other details where high local humidity peaks may occur.

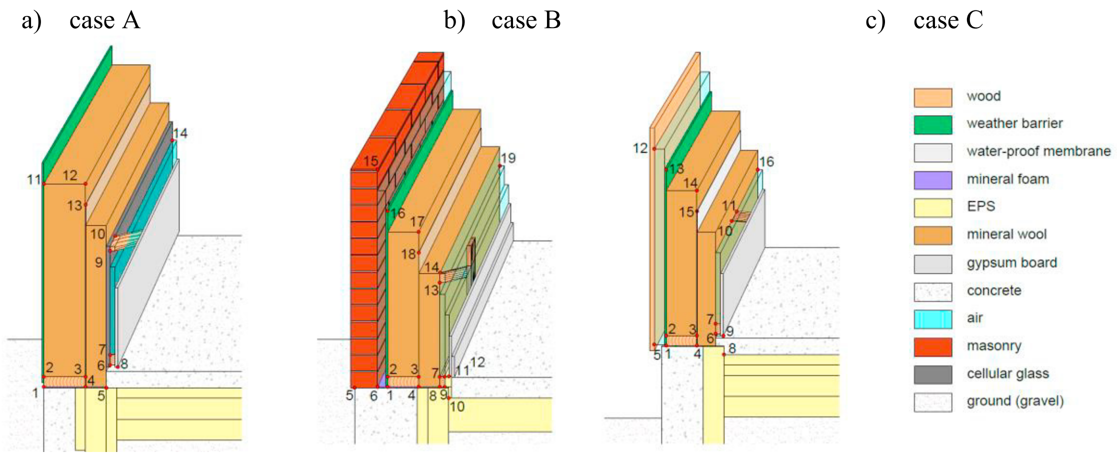

Fig. 1. Geometry of studied cases and location of analysed points: (a) case A shows timber-framed structure where no exterior air-gap is included; (b) case B represents timber-framed structure with brick outer-cladding; (c) case C represents timber-framed structure where outer-cladding is separated by air-gap.