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Analysis and Design Rehabilitation Foundation of Timber Houses in Scandinavian Climate Condition

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Abstract

The article describes the analysis and remediation design of the rudiments walls of Wooden construction in the "two by four" system in Central Europe, in particular the Scandinavian climate. This article is focused on the real problems, which these constructions face in similar conditions. Especially in Scandinavian climatic conditions the specific requirements for the solution of this detail must be fulfilled, including the requirements on foundation base frost penetration, minimum interior surface temperature and prevention of the accumulation of moisture in the structure. These structures are facing many bottlenecks already stemming from the architectural and operational requirements that have significant influence on the outcome of the detail. The article is focused on one of the most common structural solutions, which in construction practice could be found mostly in houses built between years 1960 - 1970. The article is focused on the most common rehabilitation of this detail as well. Both of details are subjected to dynamic heat and moisture analysis and analysis of mold growth. The results pointed out on critical solution of the original and rehabilitated foundation and evaluation of the implementing remediation design. To determine the required temperature curve and humidity Wufi 2D software was used.

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Keywords: foudation; rebabilitation; lower parts of walls; timber house; thermal and moiscure analyst; mould growth index; Wufi 2D

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1. Introduction

In Northern Europe, the roofs, floors and lower parts of walls are most often exposed to high humidity and potential attack by biodeterioration processes [1] when also decay will develop. The article is focused to on the structural details of lower parts of wall - the connection of wall and foundation. The emergence of defects in this part of the structure is frequently connected with dysfunctional ventilation cavity, which could be blocked by mortar or soil. Soil may be pile up high over the line of ground floor or on the contrary could be reduced on the way to foundation base and therefore preclude function of ventilated air gap in the wall. The defects that arise on assessed details are connected with buildings from 1960 and 1970. There occurs excessive accumulation of moisture in the construction and material degradation. The excessive amount of water in the building structure and materials is the basic cause of different bio-deterioration problems like decay. If ventilation gaps are closed, severe decay problems have been found, e.g. dry rot damage [5]. The article describes the dynamic moisture and heat model with mould growth index evaluation. Two types of structural details are evaluated. Both of these models, the original detail and the rehabilitated detail, are exposed to the Scandinavian climate. Both are common details of timber houses in two by four system, strip foundations and wall with air gap. This is very common structural solution in this region. Simulation is solved by three variants of a structural solution. Detail D1-01 is a case where a ventilated cavity is blocked by mortar, detail D1-02 is case where adjacent soil is reduced against original terrain, in D1-03 the adjacent soil is raised compared to the original terrain. Detail D2-reh represents the most frequently used design of rehabilitation and reconstruction of this detail.

2. Wufi 2D Analysis

To analyze the structural detail, the simulation dynamic tool WUFI 2D is used. WUFI computational model was created based on the work of H. M. Künzel, which is based on the system of differential formulas (1) for temperature and (2) moisture.

$$\frac{dH}{dT}\cdot\frac{\partial T}{\partial t}=\nabla\cdot(\lambda\cdot\nabla\cdot T)+h_v\cdot\nabla\cdot(\delta_p\cdot\nabla(\varphi\cdot p_{sat})) \tag{1}$$

$$\frac{dw}{d\varphi}\cdot\frac{\partial\varphi}{\partial t}=\nabla\cdot(D_\varphi\cdot\nabla_\varphi+\delta_p\cdot\nabla\cdot(\varphi\cdot p_{sat})) \tag{2}$$

The numerical dynamic model allows unlike stationary standardized procedures set out this point [10]:

- dynamic simulation of heat and moisture transport in structures with any time steps,
- set the orientation to cardinal and horizontal
- the influence of solar and longwave radiation to heat diffusion and moisture transport
- dependence of the thermal conductivity of the material to the amount of moisture in the material
- dependence diffusion resistance factor on the amount of moisture in the material
- the spread of liquid moisture in porous materials
- include the absorption of driving rain on the outer surface of the structure.

3. Mould growth index

Modelling of mould growth and decay development based on humidity, temperature, exposure time and material will give tools for the evaluation of durability of different building materials and structures [1]. In Scandinavic countries the structures are evaluated from the viewpoint of moisture through so called Mould growth index, created by Viitanen [13]. The index describes the percentage of the element surface which is covered with mould. The maximum value depends on the current conditions in to which the element is exposed. In the case of a timber the index is determined according to equation (3).

$$M_{max}=1+7\cdot\frac{RH_{crit}-RH}{RH_{crit}-100}-2\cdot\left(\frac{RH_{crit}-RH}{RH_{crit}-100}\right)^2 \tag{3}$$