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Moisture robustness assessment of a window with integrated solar screen using numerical and experimental methods

Steinar Grynning[a*] Christian Schlemminger[a] and Sivert Uvsløkk[a]

[a]*SINTEF Building and Infrastructure, department of Architecture, Materials and Technology, Trondheim, Norway*

Abstract

In this study, a wood-frame window with an integrated exterior solar shading unit has been investigated.

Numerical simulations have been carried out to quantify the moisture distribution and drying-out rate of the construction detail. The simulations have been compared to measured data from an ongoing experimental study.

The results indicate that built-in moisture in the wall can lead to high levels of relative humidity (RH) in the detail and that design of this detail should be done considering this. Simulations showed that unfavourable RH-levels can be avoided if it is optimally designed. Preliminary measurements indicate the same trends.

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Keywords: window; solar shading, screen; moisture, drying-out rate; experimental; numerical simulations

1. Introduction

Modern buildings have very low heating demands in general. A direct consequences of such low heating demands, is that cooling demands are becoming a dominating factor in buildings, even in what is commonly considered a heating-dominated Nordic climate. Thus, it becomes obvious that shading devices are necessary in order to reduce cooling demands as well as to maintain a satisfactory thermal comfort.

As a response to this, new solutions are emerging on the market. One such solution is to integrate solar shading units in the windows, where the aim is to make an easy-to-handle integrated system for both craftsmen and end-users of the system. Such a system has been developed by a Norwegian window manufacturer.

However, the introduction of a vapour-tight unit like the shading device casing (as shown in Figure 1) in the outer (cold) part of a wood frame wall can lead to moisture related problems. The need for development of well-functioning

* Corresponding author. Tel.: +47 975 66 103
E-mail address: steinar.grynning@sintef.no

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technical solutions of the building envelope and other parts with respect to both strategies and solutions was demonstrated in [1, 2], who, by examining the SINTEF Building and Infrastructure building defects archive, found that 75 % of damages and defects in the Norwegian building stock could be related to moisture damages and furthermore that 66 was related to the building envelope. To underline the importance, it must be noted that the total annual costs related to repairs of buildings in Norway amount to roughly 1.65 billion Euros [3].

Criteria for mould growth potentials and moisture robustness have been the subject of several previous studies, where a thorough review of the current knowledge is given by Gradeci et.al. [4]. Viitanen [5] established the most used criteria in 1997. Viitanen concluded that the relative humidity (RH) must be higher than 80 % (corresponding to a wood moisture of 20 weight-% at 20°C) for a period of five months for mould growth to be initiated. If the RH increases to 90 %, the initiation period is reduced to four weeks. This is the basis for the criteria used in the SINTEF Building and Research Design Guidelines where the following criteria must be simultaneously fulfilled for mould growth to be initiated: 1) moisture content in wood must exceed 20 %, the period of wetting, 2) The wetting-period must be longer than 4 weeks 3), the temperature must exceed 5°C. These criteria are assessed to be conservative [6].

In this study, a wood-frame window with an integrated exterior screen solar shading unit has been investigated. The screen is mounted in a casing made of aluminum mounted on top of the wood-frame. The introduction of the aluminum casing reduces the drying-out capability of the construction in this area. Numerical simulations, using a 2D finite-element software, have been carried out in order to quantify the moisture distribution and drying-out rate of the construction detail. The results from the numerical simulations have been compared to the initial measured data for the solution from an ongoing experimental study of the same detail. This paper presents initial measurements from the first period of the measurement campaign. The experiment was carried out measuring moisture levels and temperatures in a full-scale build-up of the sample placed in an exterior wall facing real climatic conditions.

2. Methodology and shading device description

2.1. Numerical simulations

Calculations have been carried out using the WUFI 2D tool [7], which is a two-dimensional hygrothermal simulation software. A study of moisture contents and levels considering the design of the detail have been carried out. Fig. 1 (right) shows the WUFI modeling domain. The accuracy of the software have previously been studied by [8] and [9] who concluded that the software was a good tool for determination of the moisture performance of a facade

In order to reduce the complexity and simulation time of the numerical model, some simplifications of the model were made. Simulations have been carried out for a two-year period in order to investigate seasonal drying-out and wetting of the detail. Weather data for a standardized climate-year from Værnes Trondheim, with an average mean temperature of 7.6°C has been used. An interior climate corresponding to Humidity class 2, Offices, dwellings with normal occupancy and ventilation" from NS-EN 13788 [10] has been used. This corresponds to a moisture supply of 4 g/(m³h). This is assessed to be a conservative assumption for well-ventilated buildings.

The head of the window frame is simplified and modeled as a rectangular profile. An adiabatic boundary is set on the lower edge (shown in green on Figure 1 (right)) of the rectangle representing the window head. This gives that no heat or moisture are transferred through the surface, making it a conservative situation in terms of the total drying-out capacity of the detail. The gaskets between the head and aluminum casing are ignored and the frame is modeled in direct contact to the aluminum casing. The cavity inside the aluminium casing is modelled as stagnant air.

2.2. Experimental methodology and set-up

The window with the exterior screen solar shading unit is installed in the ZEB Test Cell Laboratory. The facility is designed to carry out calorimetric, comparative and tests with occupants, on full-scale building envelope systems. The ZEB Test Cell consists of two test cell rooms – internal dimensions (W x L x H): 2.4 m x 4.2 m x 3.3 m – each surrounded by a guarded volume to eliminate heat exchange. The south wall of each test cell room is exposed to real outdoor conditions, having an area (W x H): 2.4 m x 3.3 m. The indoor air condition of the test rooms allows desired conditions.