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Behavior of wooden based insulations at high temperatures

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Abstract

Insulation materials may give a different contribution to the fire resistance of timber frame assemblies. At present, Eurocode 5 Part 1-2 [1] provides a model for fire design of the load bearing function of timber frame assemblies with cavities completely filled with stone wool. The extension of this model for glass wool for post protection phase has been published in the European technical guideline Fire Safety in Timber Buildings [2]. Very little is known about the protection of bio-based insulation materials. Eight model scale furnace tests of floor specimens were carried out. Two different design tools to calculate the charring rate of timber frame assemblies insulated with wooden based insulations are provided. The first one is a design model for timber frame assemblies insulated with batt-type and loose fill cellulose fiber insulations. The second tool includes the functions of conductivity, specific heat and loss in mass against the temperature calibrated on the standard fire curve to implement advanced heat transfer calculations. The purpose is to give the designers two design procedures with a different level of complexity and accuracy.

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*Keywords:*cellulose fibre insulations, timber frame assemblies, fire resistance

1. Introduction

New technologies are constantly being developed to complement current practices in creating greener structures, by reducing the overall impact of the built environment on human health and protecting occupant health. A similar concept is natural building, which is usually on a smaller scale and tends to focus on the use of natural materials that are available locally [3].

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A solution commonly used to build natural buildings is the light timber frame structure with the cavity completely filled with wooden based insulation. This solution is used mostly in new buildings, however the technique can be used also for deep renovations.

The behavior of timber frame assemblies in fire is influenced by the protective properties of cladding and insulation materials. The primary protection for a timber member is given by the cladding. The charring of a timber member protected by cladding is considered the protection phase. After the fall-off of the cladding, secondary protection might be provided by insulation materials. The charring of a timber member after the fall-off of the cladding is regarded as the post-protection phase. Annex C of the current Eurocode 5 Part 1-2 [1] presents a design model that considers the contribution of stone wool. The model is extended to assemblies filled with glass wool until the failure of the claddings. The European guideline Fire Safety in Timber Buildings (FSITB) [2] includes a design model that considers the contribution of glass wool to the fire resistance during the post-protection phase. All the other insulation materials are excluded in the models described above.

The EN-standard dealing with factory made wood fiber thermal insulations for buildings refers to the performance in terms of reaction to fire and does, therefore, not provide information on fire resistance performance [4].

The model presented in the Eurocode 5 Part 1-2 was developed by König and Walleij [5]. It considers a one-dimensional charring, simplifying the residual cross section into a rectangular one, and introduces coefficients that correct the nominal charring rate to take into account the corner roundings. The greater charring depth for narrow elements is taken into account through the coefficient k_s, which depends on the width of the original cross section. To transform the real charred cross section into a rectangular one, the coefficient k_n is used, based on the ratio of section modulus of the real and simplified cross-sections. The protection coefficients describe the different charring rates in the protection and post-protection phase. The coefficient k_2 considers the protection of gypsum plasterboard, while k_3 considers a greater charring rate during the post protection phase and it depends on the failure time of the fire protection.

The design model for timber frame assemblies protected with glass wool inserted in FSITB was proposed by Just [6]. It also considers charring from the lateral sides, with different starting times at the top and bottom of the side; giving the residual cross section a trapezoidal shape. This introduction was made due to a faster recession of the glass wool compared to stone wool in the fire condition.

Recent studies demonstrated that the design model included in Eurocode 5 can be used to predict the charring depth of timber members completely filled with insulations other than stone wool [7]

A lack of information and limited investigations performed have raised the necessity to develop a design model that considers the contribution of wooden based insulation materials to the protection against charring of timber members.

The purpose of this paper is to give the designers two different design procedures for calculating the charring rate. The simplest one, using calculation methods, and an advanced one, which allows implementing the cellulose fiber in heat transfer models. The aim is to achieve higher accuracy with the more advanced method.

2. Methodology

The contribution to fire resistance of timber frame assemblies given by three different wooden based insulations was studied by means of model scale furnace tests. The specimens consisted of timber beams and the applied insulation materials. The insulation materials involved in this investigation are cellulose fiber in loose fill type in its original composition (OF), the same loose fill cellulose fiber impregnated to improve fire resistance (FF) and cellulose fiber in batt-type (BF).

Furthermore, a series of thermal simulations by means of SAFIR (v2014a1) were carried out.

2.1. Model scale furnace tests

Eight specimens of timber frame assemblies were tested in horizontal position in a cubic meter furnace following the standard fire curve according to ISO 834 [8] (Table I). The specimens consisted of a timber beam the sides of