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Performance of Constructions with Clay Plaster and Timber at Elevated Temperatures

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Abstract

The combustibility of timber is one of the main reasons that too many building regulations and standards restrict its use. Lack of understanding of the fire technical properties of clay plaster is what most likely prevents this traditional material in combination with timber from being widely used. The purpose of the following research is to designate the fire technical properties for clay plaster for the fire design of timber structures. For this study the fire testing of clay plaster was carried out in small and model scale to determine the main characteristics. In this paper the recommendations for the improvement of the design method for timber structures with clay plaster according to the safety philosophy of Eurocode 5 Part 1-2 are published.

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Keywords: timber constructions ; fire design ; clay plaster ; EN1995-1-2 ; cross-laminated timber

1. Introduction

There is an increasing challenge to reduce the energy and environmental impacts from the construction sectors. It has been recognized that traditional and ecological building materials could be perfect for utilizing sustainable design principles. Timber as one of the most versatile renewable resources and large-scale construction materials is acknowledged to have a great potential to improve the development of energy efficient buildings. Innovative new

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building technologies and development in product design enable a wide range of different solutions in timber constructions that minimize the future environmental impact.

In addition, the demand for a more sustainable and healthier indoor environment is increasing. Therefore, there has been a growing interest in nontoxic, reusable and recyclable materials together with low embodied energy. At the same time in order to reduce the operational energy use in built environment, the passive role of building materials has become an important factor to investigate. It has been scientifically explained that exposed surfaces of clay plaster act as a passive regulator of internal humidity level due to its excellent hygroscopic and vapour permeable properties [1].

Historically, clay plaster has been used in various construction techniques with timber. Clay has been neglected by modern materials in the last decades but it has been once again recognized and there is a growing interest towards a wider use of clay products. However, nowadays the restrictions of the fire design of timber structures are one of the main reasons for limiting the use of traditional materials. Fire safety has been one of the earliest issues addressed by building regulations and is currently an essential parameter to be investigated in building design.

In general, one of the main obstacles for the wider use of timber is the combustibility of timber. The standard for structural fire design of timber structures, EN 1995-1-2 [2], provides some information for protection materials but it has no information concerning plasters. This is most probably because of the minimal amount of knowledge about the fire technical properties of clay plaster in conjunction with timber structures.

The fire resistance of timber is generally determined by full-scale furnace testing. However, full-scale testing is highly complex and expensive tool for the verification of the fire resistance of different timber combinations. In this presented study, a small scale testing appeared to be the most reasonable testing method to examine the basic properties of clay plaster as a fire protection material since there are a large number of possible combinations of timber and different mixtures of clay plaster available.

In this paper a short introduction about the main conception of the fire design of timber structures and clay plaster as a protection material is presented. For this study the fire testing of clay plaster was carried out in small and model scale to determine the main characteristics of clay plaster which influence the fire technical properties of clay plaster the most. A short overview of the initial study on protective effect of clay plaster in small scale investigated by Liblik in her master thesis [3] is introduced. The results of this paper provide future development in a wider use of natural building materials.

Nomenclature

t	time (min)
t_{ch}	start time of charring (min)
$d_{\mathrm{char.0}}$	charring depth for one-dimensional charring (mm)
d	thickness of timber member (mm)
h_{p}	plaster thickness (mm)
β_0	one-dimensional charring rate (mm/min)
$\beta_{0.2}$	reduced one-dimensional charring rate (mm/min)
k_2	protection phase factor
T	temperature (˚C)

2. Design of timber structures

2.1. Design principles

The fire design of timber structures is specified in EN 1995-1-2 [2]. It describes the principles, requirements and rules for the structural design of timber structures exposed to fire.

One of the main objectives of structural fire safety is to guarantee the load-bearing capacity of the structure for a required period of time. The required time is specified by the building regulations. The resistance to fire concerns structural elements which must withstand a fully developed fire while fulfilling certain requirements. The fully developed fire is described by the standard temperature-time curve given in ISO 834 [4]. Charring is generally the