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Fire resistance of timbers from tropical countries and comparison of experimental charring rates with various models

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Abstract

Tropical hardwood species are more and more used in the field of construction due to the particular qualities they can offer. Presently it is no longer possible to envisage the development of construction materials and products without taking into consideration the problem of their fire behaviour, and more particularly of their fire resistance. In the case of timber elements, this characteristic is mainly influenced by the charring rate of the external layers of the element. On the other hand this parameter is influenced by the density of the material.

Limited information is available on the charring rate of tropical hardwood species. Therefore experimental investigations have been conducted at the University of Liege to study this characteristic. Seven tropical and three timber species from temperate countries have been examined. Two types of test have been used, one on small specimens, the other on a construction element made of one single material. In the first type, 20 specimens have been manufactured by gluing several laminates together. The specimens were instrumented with four thermocouples inserted at various depths in four different laminates. In the second type, a non-loaded wall made of 12 glued-laminated spruce beam profiles was instrumented with thermocouples embedded at different depths in the panel for the evaluation of the charring rate.

Experimental charring rates have been compared with the results derived from Eurocode EC5-1.2 recommendation [ENV 1995-1-2. Eurocode 5: Design of timber structures – Part 1–2: General rules – Structural fire design. European prestandard; 1994], Australian standard AS 1720.4 relation [AS 1720.4. Timber structures Part 4: fire resistance of structural timber members. North Sydney, Australia: Standards Australia; 1990] and White's model [Charring rates of different wood species. PhD dissertation. Madison University of Wisconsin, Madison, WI, 1988; White RH, Erik V, Nordheim EV. Charring rate of wood for ASTM E119 exposure. Fire Technol 1992;28(1)]. This comparison shows that the results obtained from these three models are not entirely satisfactory for tropical hardwood species. Therefore a new model has been proposed.

Keywords: Timber; Tropical hardwood; Fire test; Fire resistance; Modelling; Charring rate

1. Introduction

In Belgium, wood is widely available. More particularly, in Wallonia, the southern part of Belgium, wood is of excellent quality for building purposes. However hardly 8% of the Belgian building patrimony is realized with this material, while in other continents or countries such as North America, Scandinavian countries, New Zealand, Germany and Switzerland, timber is used extensively in the field of construction. The main reasons for this low use are related to building tradition and also to some lack of confidence in the performance and durability of timber construction, which is very often groundless.

Despite the good quality of Belgian wood, tropical hardwood species are frequently being used in Belgium and in Europe for the particular qualities they can offer.

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Nomenclature

c	hardwood (−1) – softwood (+1) classification	β_{test}	experimental charring rate, mm/min
d	transport property of wood species	ρ_H	air-dried density, kg/m^3
m	reciprocal of charring rate, min/mm	ρ_{12}	density at 12 percent moisture content, kg/m^3
t	time, min	ρ_k	characteristic density, kg/m^3
x_c	charred depth from original fire-exposed surface, mm	ω	moisture content, %
β	notional charring rate, mm/min		

It is presently no longer possible to envisage the development of construction materials and products without taking into consideration the problem of their fire behaviour, and more particularly of their fire resistance.

Timber is an inflammable and combustible material, but its fire resistance characteristics are considered to be satisfactory. In fact during the exposure to fire a charred layer forms on the external part of the timber element, that protects the underlying layers against the action of the fire. Therefore the residual section of the beam or of the column decreases slowly and the element loses only very progressively its structural capacity. The main parameter in the study of the fire resistance of timber structural elements is therefore their charring rate. This parameter is influenced mainly by the density of the material. Other factors have also an influence on the charring rate such as, for example, the moisture content. This factor has not been considered here because the moisture content was very similar in all specimens. Except for one specimen, the moisture content varied between 9% and 13%, i.e., very close to the value of 12% that is usually considered as the standard condition for testing mechanical properties of wood. This value of 12% also corresponds to the moisture content in timber members that are classified in Service Class 1 according to Eurocode 5, i.e., timber members located in a dry environment such as the interior of a building construction.

The main purpose of this research study is to analyse the charring rate of various timber species submitted to a standard fire [1,2], more particularly of tropical hardwood species, and to recommend a model to assess this characteristic in relation to the density of the material.

As there is limited information available on the charring rate of tropical hardwood, it has been decided to perform experimental investigations at the University of Liege to study this characteristic. Two types of test have been used. The first procedure has been developed at the University of Liege. Specimens have been manufactured by gluing several laminates together and instrumented with thermocouples inserted at various depths in different laminates. The second test consisted of a fire resistance test performed on a full scale non-loaded wall made of spruce. The wall has been instrumented with thermocouples embedded at different depths in the panel for the evaluation of the charring rate.

In order to make a proposal for the charring rate, these experimental results have to be compared with values recommended in various standards like EC5 [3] and those obtained from empirical models. This comparison will show if these models are appropriate for design purposes when tropical hardwood species are used. If not, a new model will be proposed.

2. Literature background

The charring rate of both softwood or hardwood timber exposed to the standard time–temperature curve [1,2] has been studied in United States [4–6], Sweden [7], Australia [8], New Zealand [9] and Malaysia [10]. All these investigations show that the density of wood has a major influence on this characteristic but tropical species have hardly been considered in these research works.

It is known that, due to the lack of a standard test procedure for determining charring rates, the results found in the literature may have been obtained in different ways. König and Waleij [7], for example, proposed to define a basic charring rate as the charring rate corresponding to one-dimensional heat transfer conditions.

Several empirical models have been developed [4–6]. One of these and two methods proposed in standards currently used for fire design of timber construction have been compared with the experimental results obtained in this study.

2.1. Eurocode 5 recommendation

EC5 assumes that the charring rate of timber made of solid or glued-laminated hardwood decreases linearly