ARTICLE IN PRESS

Construction and Building Materials xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Improvement of fire reaction and mould growth resistance of a new bio-based thermal insulation material

M. Palumbo [a,*], A.M. Lacasta [b], A. Navarro [b], M.P. Giraldo [b,c], B. Lesar [d]

[a] Dept. de Engenharia Civil, Universidade Federal Fluminense, R. Passo da Pátria 156, Niteroi, RJ, Brasil
[b] Universitat Politècnica de Catalunya, Barcelona School of Building Construction, Av. Doctor Marañon 44, 08028 Barcelona, Spain
[c] CTFC – Forest Sciences Centre of Catalonia, Ctra. de St. Llorenç Km 2, Solsona, Spain
[d] University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology, Jamnikarjeva 101, Si-1000 Ljubljana, Slovenia

HIGHLIGHTS

- The fire behaviour and fungal resistance of a new bio-based insulator is analysed.
- Low toxic fire retardants and biocides are incorporated and their effect evaluated.
- Boric acid and aluminium hydroxide slow down the smouldering combustion process.
- Among the tested substances, only boric acid prevented mould growth at high RH.

ARTICLE INFO

Article history:
Received 30 June 2016
Received in revised form 31 October 2016
Accepted 4 November 2016
Available online xxxx

Keywords:
Corn pith
Maize
Alginate
Thermal insulation
Fire behaviour
Smouldering combustion
Fungal attack

ABSTRACT

In the present paper, the performance of an innovative thermal insulation rigid board is evaluated in terms of fire behaviour and fungal resistance. The board is based on vegetal pith and a natural gum (corn pith and sodium alginate) and it is completely compostable. This new composite was developed in previous work. Here boric acid, aluminium hydroxide and ammonium polyphosphate are used as fire retardants and montan wax, acetic acid and lactic acid are used as water repellent and fungicides respectively. Interactions between these different treatments is investigated. Both flaming and smouldering combustion processes of the different formulations are evaluated by small-scale techniques which include pyrolysis microcalorimetry and thermogravimetric analysis. A medium-scale device is also designed in order to study the impact of the different additives to the smouldering kinetics. Fire behaviour tests show that good improvement is obtained, both in flaming and smouldering combustion when boric acid is added. Although smouldering is not avoided in any case, the addition of 8% of boric acid or aluminium hydroxide slows down the speed of combustion propagation. The effect of the different additives on the moisture content and mould growth at 97% RH and 27 °C is analysed. Under such severe conditions none of the additives is able to prevent mould growth, with the exception of boric acid. None or marginal mould growth was observed on samples containing 8% of boric acid although moisture content was higher than the other cases.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The use of low embodied carbon and locally available building materials for energy refurbishment is gaining interest in the recent years as the sector is moving towards new approached to energy efficient design.

The use of crop by-products as raw materials in building insulation products might contribute in this respect [1–3]. Together with the good hygrothermic properties of these natural materials, their availability from renewable resources is considered as one of their main advantages compared with other petroleum-derived insulations [4]. In addition, the use of crop by-products has a positive environmental impact because implies the revaluation of accumulated agricultural waste. All of these beneficial aspects encourage their use in building insulation, but it is necessary to analyse their potential response under real conditions. In particular resistance to fungal attack and fire behaviour are the two main issues to be considered before establish the feasibility of their use. In this research, the performance of an innovative thermal

* Corresponding author.
E-mail address: mariana.palumbo@upc.edu (M. Palumbo).

http://dx.doi.org/10.1016/j.conbuildmat.2016.11.020
0950-0618/© 2016 Elsevier Ltd. All rights reserved.

Please cite this article in press as: M. Palumbo et al., Improvement of fire reaction and mould growth resistance of a new bio-based thermal insulation material, Constr. Build. Mater. (2016), http://dx.doi.org/10.1016/j.conbuildmat.2016.11.020

insulation rigid board is evaluated. The board is based on corn pith agglutinated with sodium alginate [4,5]. Here, the corn pith is pre-treated with different substances i.e. boric acid, aluminium hydroxide, montan wax, acetic acid and lactic acid before forming the board in order to improve the fire reaction and fungal resistance of the material.

1.1. Fire reaction

Several authors have analysed the thermal degradation and flammability of different natural fibres and composites that include such fibres [6–8]. In a previous paper [9], the fire behaviour of experimental insulation materials based on food crop by-products (rice husk, barley straw and corn pith) and natural binders (sodium alginate and corn starch) was evaluated. Both, small-scale pyrolysis combustion flow calorimetry (PCFC) and fire reaction tests indicated that the fire properties of the six experimental natural insulation materials were very favourable when compared with other organic foamy materials commonly used in building insulation, such as polystyrene and polyurethane. The use of alginate as a binder improved the properties of the crop by-product alone, especially in the case of corn pith, where both the total heat release HR and the peak of heat release rate PHRR were reduced by 30%.

In addition to flaming combustion, that take place in gas phase between the generated volatile gases and oxygen, smouldering was also observed in corn pith based panels [9]. Smouldering is a slow flameless form of combustion that is sustained by the exothermic surface reaction between solid fuel and oxygen. This type of combustion is characteristic of porous materials which form a solid carbonaceous char when heated, and is frequently observed in cellulosic materials [10–12]. Smouldering propagation is about ten times slower than flame spread over a solid. In spite of its weak combustion characteristics, smouldering is a significant fire hazard. The initiation and propagation of smouldering are controlled by several interrelated factors as surface area per unit mass of fuel, permeability and thermal insulation [11,13,14]. He et al. [15] investigated the reaction heat of agro-stalks using a simultaneous thermal analyser (STA), in air, using a crucible with lid. Based on the analysis of the DSC curves, oxidative polymer degradation heat and char oxidation heat were obtained from experimental data. Ohlemiller et al. [16] analysed both unretarded cellulosic insulation and insulation having 25 wt% of the smoulder retardant, boric acid, added on. Boric acid was unable to halt the smoulder process but it slowed its spread by about a factor of 2.

The strategy commonly used to analyse both flaming and smouldering combustion combines small-scale thermal analysis such as Microscale combustion calorimetry (PCFC), Thermogramivetric Analysis (TGA) and/or Differential Scanning Calorimetry (DSC) with fire reaction tests. Several medium-scale devises have been proposed by different authors [12,16,17] to analyse the kinetics of smouldering processes.

1.2. Mould growth resistance

Bio-based materials have been used in construction for centuries and can last many thousands of years under proper conditions. However, they can also degrade due to the action of microorganisms such as fungi or bacteria which compromises their durability. The activity of such microorganisms depends on environment factors, mainly moisture and temperature and on the substrate characteristics such as nutrient content or hygroscopicity.

Crop by-products, like other bio-based materials, represent a potential source of nutrients for fungi and bacteria. However, under the same environmental conditions, they are not equally affected by mould growth. Their resistance against mould growth determines their suitability for application and is generally assessed in terms of critical moisture content or of the limit environment conditions from which mould growth is possible. Hofbauer et al. [18,19] proposed to use an isopleth system to create a material specific profile showing at which climatic conditions (temperature and relative humidity) similar mould activity takes place. They found that bio-based materials present extremely different resistance profiles: hemp showed a rather high resistance to mould growth (similar to mineral based materials) while straw was far less resistant.

Nevertheless, the mould growth resistance of a material can be improved with the addition of biocides. Boric acid and derived salts such as borates are commonly used as biocide in some commercial insulation materials such as blowing cellulose (e.g. Homatherm flexCL, Thermaflox and Isocell cellulose insulations). Such substances have the advantage to act both as a biocide and as fire retardant and used to be considered a greener alternative to metal based fungicides, commonly used in wood preservation. However nowadays their toxicity is under evaluation and their use is limited by the European regulation and the international GHS to a concentration under 5.5% (w/w) of the final products [20]. In previous work (unpublished) Lesar compared the fungal and fire resistance of cellulose insulation boards treated with boric acid and aluminium hydroxide. They used different percentages of both products and found that a mixture of 3% of boric acid and 6% of aluminium hydroxide gave the best results. The use of lactic acid bacterium may be an environmental friendly alternative to boric acid and its derivatives. The fungal inhibition action of lactobacterium has been largely studied on food products. Among the metabolites of such bacterium, lactic acid and acetic acid are often detected but it is not clear to which extend they are responsible of their antifungal activity [21]. Ocallahan [22] used a lactobacillus brevis cell-free supernatant to impregnate pine wood samples and found that treated timber exhibit resistance to degradation from all fungi studied. Acid and lactic acid were detected as main metabolites of these lactobacilli. Yang [23] found that a 1:2 dilution of L. casei supernatant inhibited growth of three mould -and one stain fungus associated with wood-based building materials. Lactic acid was identified as one of the produced metabolites, but antifungal activity was attributed to one or more unknown metabolites.

A further approach, which is gaining importance in the last few years, is the use nonbiocidal techniques for protection against fungi. Bio-based raw materials can be impregnated with water repellents, such as waxes [24], or pre-treated to reduce their hygroscopicity. Treatments with acetic anhydride [25,26] or laccase mediated grafting are two examples of such treatments [27,28].

2. Experimental

2.1. Board formation

Specimens were made using corn pith that was manually removed from corn stalks, grinded and sieved to form a 4–2 mm diameter granulate. This was then pre-treated with a 3% water solution of boric acid, aluminium hydroxide, ammonium polyphosphate, montan wax, acetic acid or lactic acid. The amount of additive incorporated (weigh, dry basis) in each specimen is shown in Table 1. The pre-treated granulate was bonded with 3% of sodium alginate (weigh, dry basis) andthen, 1% of calcium sulphate dihydrate ($CaSO_4{\cdot}2H_2O$) was added as a source of Ca^{2+} ions to achieve alginate gelation. The blend was energetically stirred and was thereafter poured in a mould and hot pressed at 60 °C for 10 min to a target density of 50 kg/m^3. The target density was achieved

Please cite this article in press as: M. Palumbo et al., Improvement of fire reaction and mould growth resistance of a new bio-based thermal insulation material, Constr. Build. Mater. (2016), http://dx.doi.org/10.1016/j.conbuildmat.2016.11.020

Download English Version:

https://daneshyari.com/en/article/4913523

Download Persian Version:

https://daneshyari.com/article/4913523

Daneshyari.com