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ScienceDirect

Energy Procedia 139 (2017) 544–549

Energy

Procedia

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International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

Impact of fiber treatment on the fire reaction and thermal degradation of building insulation straw composite

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Abstract

In this paper, both treated and untreated straw fibers are used to manufacture the light-weight composite for building insulation. The main objective of this work is to investigate the effect of the treatment on the thermal degradation and flammability of the material in order to examine his fire behavior. The selected wheat and barley straws are mixed with lime or gypsum plaster in this experimental investigation. In order to improve the mechanical properties of the composite, the straw fibers are treated with linseed oil and boiled water for decreasing their water absorption and increasing their compatibility and adhesion with the binder respectively. The treatment is carried out by total impregnation in the boiled water and linseed oil. The different composites are manufactured using mixture procedure optimized in previous works of the authors. Then the treated and untreated composite specimens are analyzed and compared through TG-DSC analysis to study their combustion process at microscopic level, and flammability test to study their fire reaction at macroscopic level. The properties of composites based on the fibers treated with linseed oil vary significantly.

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Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016.

Keywords: fire rection, fiber treatment, building insulation, staw composite

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1. Introduction

Addition of low density biodegradable natural fibers to mineral or polymer matrix present attractive alternatives to synthetic fibers for different applications with various performances, and low environmental impact. Most of these composites have been developed in order to reduce weight and produce environmentally friendly materials in particular in building sector resulting in a decrease of energy consumption of the building and the reduction of the GHG emission. In the recent years, several research have been undertaken on the production of innovative materials with specific properties and mechanical performance [1, 2]. However, many major difficulties limit the large use of natural fibers for structural applications, like their low strength compared to metals and polymers, water absorption and low fire resistance. These factors results inadequate properties for many purposes. Then, the treatment of fibers is an area of research more important for improve the properties of the natural fiber composites [3, 4]. These treatments improve significantly the mechanical properties but it is difficult to find a single effective treatment for all properties. Few analysis are carried out for example to examine the effect of these treatments used generally for mechanical properties on the thermal degradation and fire behavior. This is an important point to establish the use conditions and performance criteria of the natural fiber composites in building applications [5, 6]. The fire risk is defined as the potential factor for structure and materials design [5]. The majority of the existing studies in the literature is on the polymer composites or natural fibers reinforcing polymer matrix [7-12]. The more used test for understanding the fire behavior in these investigations is the flammability test according UL94 (ASTM D3801), and TG-DSC-FTIR thermal analysis.

In this context, the present paper aims to study the fire behavior of the straw lime and straw-plaster composite proposed in the framework of a previous research program PROMETHE on the materials with low environmental impact based on the cereal straw fibers for thermal insulation rehabilitation. Samples were manufactured for the different experiments in laboratory without compaction with barley or wheat straw and lime and gypsum plaster binders [13, 14].

For thermal degradation and fire behavior, the study combines microscopic and macroscopic methods respectively, thermal analysis (thermogravimetric and differential scanning calorimetry) and reaction to fire tests ignitability in accordance with test methods and Euro-class system defined by European standardization [15]. The flammability test described in this European standards is equivalent to the UL 94 test widely used for polymer materials [15, 16]. In most investigations on composite materials used in building applications, the fire behavior is studied by flammability test, TG-DSC analysis [16, 17] and fire resistance test [18] or only PCFC calorimeter [19].

The effect of fiber treatment, the fiber variety and binder natures are examined. The fibers are treated by total immersion in boiled water and linseed oil for different times.

2. Experimental Investigation

In this laboratory experiments, the fire behavior is studied by flammability test for small flame. It is the first step to analyze the fire behavior but it is not sufficient to give the final fire classification of the composite. In this section, the brief description of the experimental work is given.

2.1. Materials

The bio-composite studied in this investigation is a new innovative material based on wheat and barley straw. The straw-concrete is made with two types of binders lime and gypsum plaster. The selection of the used natural fibers and the binder was carried out in previous studies [13, 14] in the framework of research program PROMETHE. In this work, an attention is focused on the treatment of straw fibers and the change of the thermal degradation of the bio-composite. Then, the fibers are treated before there mixture with the lime or gypsum-plaster binders. There are a significant number of studies on different treatments in order to improve the compatibility between the natural fibers and the binders and increase the tensile or compressive strength, like alkali treatment [3] or boiled water treatment [4]. In this work, two treatments are selected, boiled-water to improve the straw-surface and linseed treatment to decrease the water absorption.

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