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Characterization of corn cob as a possible raw building material

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ABSTRACT

Usually, the corn cob is considered an agriculture waste. This natural and organic waste material may be used in the industry, in general, and in the building industry, in particular. The work presented in this paper was developed in order to give a contribution to the knowledge of this material, by attempting to describe and assess its macrostructure and microstructure, elementary chemical composition, density, water absorption, fire resistance and thermal insulation capacity. These properties of the corn cob were compared with the corresponding ones of the most common thermal insulation products applied in the Portuguese building industry, which are extruded polystyrene (XPS), expanded polystyrene (EPS), cork and expanded clay. Several similarities were found when comparing the properties of these materials, in particular between the corn cob and the cork, which suggests that the corn cob may be used as a raw material to process thermal insulating products, light partition walls, ceiling coating, indoor doors and furniture, among other possible applications. The obtained results can also contribute to a more environmentally friendly building industry.

1. Introduction

Huge efforts have been done by the research community worldwide, in order to find alternative sustainable building materials and low technology methods, which result in a more sustainable and affordable construction complying with the comfort standards required nowadays. Adopting green building materials is a good option to converge to this goal. Therefore several authors [1–5] have already proposed the use of different agriculture products such as bagasse, cereal straw, corn stalk, corn cob, cotton stalks, kenaf, rice husks, rice straw, sunflower hulls and stalks, banana stalks, coconut coir, bamboo, durian peel, oil palm leaves among others for product processing such as particleboard, hardboard and fiber board. Among the agriculture products identified above, corn cob has an additional advantage, in terms of its possible application as an alternative processed product, because it does not collide with the worldwide food stock and it is generally considered as an agriculture waste. Recent research works [6–12] have given particular emphasis to its application in the industry.

In a perspective of applying corn cob as a raw or as a processed building material such as a particleboard or a sandwich panel product it is relevant and fundamental to know its properties previously. So the main goal of this paper is to give a contribution to the knowledge of this natural and organic material by attempting to describe and to assess some of its properties. The macrostructure and microstructure, the elementary chemical composition, the density, the water absorption, the fire resistance and the thermal insulation capacity properties were studied. These material properties were compared with the corresponding ones of the most frequently applied thermal insulation products in the Portuguese building industry, which are extruded polystyrene (XPS), expanded polystyrene (EPS), cork and expanded clay. Several material property similarities between the analyzed products were found, in particular between the corn cob and the cork, which suggests that the corn cob may be used as a raw material for the process of thermal insulating products, light partition walls, ceiling coating, indoor doors and furniture, among other possible applications.

This paper is structured as follows: firstly, the corn plantation and production scenarios in the last years in Portugal and in the major corn producer countries are briefly introduced; secondly, the macrostructure and the microstructure of the corn cob are presented and described as well as the microstructure of XPS, EPS, cork and expanded clay. The microstructures of these products are then compared. Plus, their elementary chemical compositions are also presented and compared; thirdly, the density, the water

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absorption and the fire resistance of the corn cob are assessed and discussed. The inherent experimental procedures applied are also explained in detail. When possible, a property comparative analysis of the above products is also done; fourthly, the potential thermal insulation capacity of the corn cob is evaluated by estimating the thermal transmission coefficient and the thermal conductivity of a specific corn cob particleboard processed for this purpose. The adopted experimental set up, to assess these measures, is also described; finally, the conclusions are drawn and the potential use of the corn cob in the industry is highlighted.

2. Corn plantation in Portugal and other countries

The corn plant, *Zea mays*, was introduced in Portugal in the mid 16th century and, ever since it has been part of the Portuguese agricultural panorama. According to ANPROMIS [13], the overall land area of the corn plantation in Portugal mainland has been facing a decreasing trend. In fact, a 53% decrease of the corn plantation land area occurred from 2004 to 2010. Meanwhile, the corn plantation land areas are basically in the north and center of Portugal mainland, corresponding approximately to 69%, of the plantation area. The south and the Portuguese islands are responsible for 31% of the overall corn plantation area.

In Portugal, the corn plantation process starts by the end of the winter (i.e. March) and can be carried out until the end of the spring (i.e. May), the harvest process takes place during the summer (i.e. between June and September). Generally, in the Portuguese context, the corn plant and the corn cereal are used for cattle food and baking industry. In contrast, the corn cob does not have any significant specific application, being occasionally used for heating, and, therefore, it is mainly considered as an agriculture waste, which is often burnt contributing consequently and unfortunately to the increase of the amount of CO_2 in the atmosphere. Finding innovative applications for this agriculture waste may result in an alternative affordable and sustainable product. The impact of this possible benefit may be relevant taking into account the overall amount of corn cob produced worldwide per year. In Fig. 1 a flowchart related to the corn production of the USA, China and Brazil, from 2003 to 2009 is presented [14]. The amount of corn produced per year has been increasing in these countries, in contrast with the Portuguese situation. Therefore, using corn cob as a possible raw building material seems opportune. Meanwhile, this fact may also reverse the decreasing trend in corn production that Portugal has been facing recently.

3. Microstructure and elementary chemical composition

As it was stated above, there are already some recent research works highlighting the potential of the application of corn cob as an alternative sustainable raw building material.

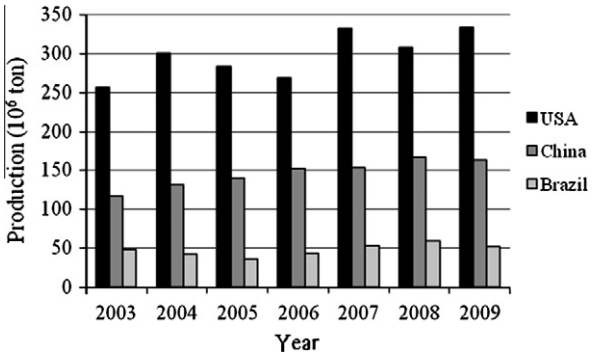

Fig. 1. Corn production in USA, China and Brazil.

A set of ancient Portuguese buildings studied by Pinto et al. [6], had corn cob applied in external walls. The macrostructure, the microstructure and the elementary chemical composition of this natural organic material and also of the extruded polystyrene (XPS) was studied by these authors. An attempt to compare these two materials in terms of thermal insulation performance was also performed. They came to the conclusion, that the corn cob can have a satisfactory thermal insulation performance, based on a comparative analysis with the XPS and due to the existing microstructure and elementary chemical composition similarities, between these two materials. The XPS was chosen in that research work, because it has been one of thermal insulation materials most frequently applied in the buildings' external walls, in the Portuguese context. The corn cob is composed by three different layers (I, II and III, Fig. 2), clearly perceived by their color, texture, shape and density, as illustrated in Fig. 2a. In terms of microstructure, the three layers also have differences. The internal layer (Layer I) presents a regular alveolar microstructure in which the alveoli have an interesting regular geometric shape, taking into account that it is a natural organic material. The alveoli have thin walls and are filled with air, Fig. 2b. This alveolar microstructure type tends to dissipate from the inside to the outside of the corn cob (from Layer I to Layer II). Furthermore, Layer II seems to have a higher density than the other two layers and also seems to have a strength capacity similar to a soft wood.

In order to complement the information reported by Pinto et al. [6], the microstructure of other thermal insulation materials frequently applied in Portugal such as expanded polystyrene (EPS), cork and expanded clay was identified. All of these materials have an alveolar microstructure and this microstructure is similar to the corn cob which improves the possibilities of using it as a building material, raw or processed. A material with low density is usually associated to this type of microstructure. It is important to underline that among these insulation thermal materials only the cork and the corn cob are natural and organic. This fact adds important relevance to this paper, taking into account that there is a multipurpose established cork industry in which Portugal is leader worldwide, which does not occur for the corn cob that is mainly an agriculture waste. In Fig. 3 the microstructure of granulated cork and expanded clay is presented.

The microstructure and the elementary chemical composition of the above materials were identified by performing a Scanning Electron Microscopy/Energy Dispersive Spectroscopy (SEM/EDS) analysis. The most relevant chemical elements identified in each thermal insulation material studied and also the corresponding percentages are identified in Table 1. The identified chemical elements are aluminum (Al), calcium (Ca), chlorine (Cl), fluorine (F), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), oxygen (O), silicon (Si) and titanium (Ti).

Generally, the most relevant identified chemical elements are O, Al and Si. None of the materials present all the identified chemical elements in their chemical elementary composition. Among the studied materials, the corn cob, the expanded clay and the XPS are the ones showing more similarities in terms of the chemical elementary composition.

4. Some properties of the corn cob

As it was stated above, in a perspective of applying corn cob as a raw or as a processed building material such as a particleboard or a sandwich panel product it is relevant and fundamental to know its properties. Therefore, the density, the water absorption and the fire resistance of the corn cob were determined. The variability associated to a natural and an organic product, such as the corn cob, increased the difficulty of this task and, therefore, the achieved