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Characterization of lightweight mortars containing wood processing by-products waste

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HIGHLIGHTS

- Reuse of wood waste for producing lightweight mortars.
- Wood mineralization through pre-soaking in calcium hydroxide aqueous solution.
- Laser diffraction particle size analysis & image analysis based on SEM for wood sawdust.

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ABSTRACT

In this study wood processing by-products were used by replacing natural sand for producing lightweight mortars. Manufacturers of wood products and furniture generate sawdust and pieces of side-cuts from a log to rectangular shapes. These are also produced by cutting, drilling, and milling operations when a wood piece is cut either from wood logs or while preparing finished products. Saw dust is often collected in filter bags or dust collectors. Three different percentages of substitution of natural sand were tried: 2.5%, 5%, and 10% by volume of the sand. Wood by-products were always pre-soaked in water and sometimes in calcium hydroxide aqueous solution in order to obtain wood mineralization before addition to the mortar mixture. Mortars containing wood by-products were characterized by means of compression and bending tests, drying shrinkage, resistance to water vapour permeability, water capillary absorption, and thermal conductivity measurements.

Results obtained showed that a maximum dosage of 5% wood by-products should be used in order to avoid an excessive loss of mortar mechanical strength, and due to the reduction of thermal conductivity of about 25%. On the other hand, if a water reducing admixture is added, adequate mechanical performance can be obtained even with 10% wood by-products.

1. Introduction

Worldwide the wood industries generate a large amount of waste products. Sawdust is generated from cutting, milling, and drilling operations when a wood piece is cut from either wood logs or while preparing finished products. Wood dust is different from wood ash (i.e. the residue produced from the incineration of wood and its products), and it consists of very fine particles generated during sanding or other machining operations, and it is often collected in filter bags or dust collectors. The physical and chemical properties of wood dust vary significantly depending on many factors such as geographical location of the log that is used for wood products and industrial processes. For example, hardwoods usually produce more dust than softwoods, and the bark and leaves generally produce more wood dust than the inner parts of the tree. On average, the wood sawing results in 5–10% by weight of dust [1]. In some cases, wood by-products contains some degree of contamination and requires further processing in order to meet end market specifications, which influence the decision for the possibility to recycle the wood by-products [2]. The generation of energy from burning wood by-products may give rise to challenges related to the CO_2 generation and the greenhouse effect. A large quantity of greenhouse gases could also be released during the storage of sawdust and wood chippings, especially if they decompose rapidly [3]. According to Höglmeier et al. [4] 26% of the recovered wood is suitable for re-use.

Some research projects have used wood ash as a replacement for cement in concrete or mortar mixtures with good results

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[5,6]. Some projects [7,8], have not shown big improvements in mechanical properties. On the other hand, the feasibility of producing limestone-bricks with wood sawdust was demonstrated by Turgut [1,9].

In their study, Bouguerra et al. [10] included wood chips (up to 8 mm) in a cement and clay matrix to test the water sorptivity. They found that macro-porous wood aggregates reduced the capillary absorption, and good thermal and insulating properties were achieved.

A new treatment of the wood chips was proposed by Coatanlem et al. [11] to improve the bonding at the wood–cement interface, consisting in pre-soaking the wood chips in sodium silicate solution.

Bederina et al. [12–14] showed that wood shavings can be added in mortars without any preliminary treatment, by reducing mortar density as well as thermal conductivity.

Quiroga et al. [15,16] studied the effect of wood treatment on the mechanical properties of wood-cement composites also by means of hierarchically structured model.

In general, the use of lightweight aggregates in concrete (such as wood chips) can be advantageous, by allowing reduced size of foundations and structural elements, as well as possibly due to the resulting improved thermal insulation. However, the most significant advantage of using lightweight aggregates in cement-based materials lies in its environmental value, in particular if the raw material used as lightweight aggregates is obtained from otherwise discarded materials, such as in this case by using wood processing by-products.

In the literature several examples of lightweight composites that contain recycled particles can be found, including waste glass [17], lightweight crushed bricks, PET waste [18], lightweight expanded clay aggregates [19], biomass ashes from paper mill sludge combustion [20], fly ash [21], GGBFS [22], waste co-incineration in cement kilns [23], foam polystyrene [24], styrene butadiene rubber (SBR) or polyurethane (PU) waste particles [25], recycled aggregates from building demolition [26–28].

In addition to the solution of environmental challenges by recycling of industrial by-products and post-consumer products, the reduction of energy consumption in construction, and the production of thermally insulating materials are also relevant issues. As a consequence, the development of composite construction materials with low thermal conductivity by using wood by-products would be an interesting alternative that may help solve simultaneously energy and environmental concerns.

2. Experimental programme

In this study an attempt was made to reuse wood processing by-products for producing lightweight mortars by replacing natural sand. Three different percentages of substitution were used: 2.5%, 5%, and 10% by the volume of sand. Wood by-products were pre-soaked in water and sometimes in calcium hydroxide aqueous solution in order to obtain wood mineralization before adding it to the mortar mixture. Mortars containing wood by-products were characterized by means of compression and bending tests, free drying shrinkage, water vapour permeability, capillary absorption, as well as thermal conductivity measurements.

Mixture proportioning and characterization of mortars were carried out bearing in mind two different possible fields of applications:

(1) as lightweight and thermal insulating plaster (for which functional properties such as lightweight, thermal insulation, low capillary absorption, water vapour permeability are more important than mechanical performance); and,

(2) as mortar for restoration (for which mechanical performance as well as drying shrinkage are the most significant properties).

2.1. Materials

Portland-limestone blended cement Type CEM II/A-L 42.5 R according to EN-197/1 [29] was used. The Blaine fineness of the cement was 0.42 m^2/g, and its relative specific gravity was 3.08. Its chemical composition is showed in Table 1.

As inert fraction, quartz sand (0–5 mm) was used. Its grain size distribution curve was determined according to EN 933-1 [30], and it is shown in Fig. 1. Then three different types of wooden by-products were used (Fig. 2):

- wood shavings (WS), 0–10 mm,
- coarse sawdust (CS), 0–8 mm,
- fine sawdust (FS), 0–2 mm.

Their value of loss on ignition was about 96%, while their relative specific gravities (evaluated according to EN 1097-6 [31]) were: 0.64, 0.68 and 0.69, respectively.

They came from three different sources, in which wood was processed to produce either frames and furniture or wood packing. The first kind (wood shaving, WS) was made of spruce (the main component), pine, oak, and mahogany. It was collected during planning, sawing, and filing. Small amounts of paint, glue, fungicide, and insecticide were present in the wood shaving by preventing a safe reuse of this wood by-product as a fuel.

The second kind (coarse sawdust, CS) was made of spruce (the main component), poplar, and beech. It was collected from sawing

Table 1
Chemical composition (oxide, %) of binders.

Oxide [%]	Cement	Class F fly ash
SiO_2	29.67	59.94
Al_2O_3	3.74	22.87
Fe_2O_3	1.80	4.67
TiO_2	0.09	0.94
CaO	59.25	3.08
MgO	1.15	1.55
SO_3	3.25	0.35
K_2O	0.79	2.19
Na_2O	0.26	0.62
Loss on ignition [%]	11.62	3.34

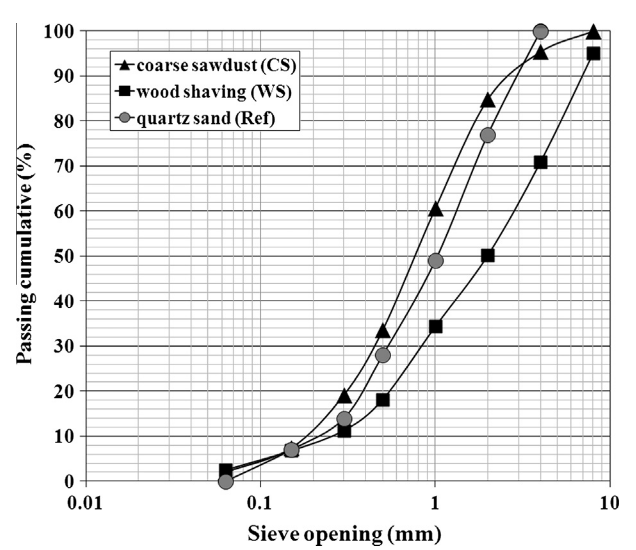

Fig. 1. Grain size distribution curves of sand and wood waste.