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Recycling of sawdust, spent earth from oil filtration, compost and marble residues for brick manufacturing

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ABSTRACT

This paper studies the application of a variety of waste materials in the production of lightweight bricks: sawdust, spent earth from oil filtration, compost and marble. First, the mineralogical and chemical composition and thermal behaviour of the wastes and clay were determined. Next, ceramic bricks were fabricated with different quantities of waste (0–10 wt.% for sawdust, 0–20 wt.% for marble, and 0–30 wt.% for compost and spent earth from oil filtration). These bricks were fired at 950 and 1050 °C. The effect of adding these wastes on the technological behaviour of the brick was assessed by linear shrinkage, water absorption, bulk density, suction absorption, compressive strength and scanning electron microscopy (SEM). The results have shown that the optimum sintering temperature is 1050 °C. Below this temperature, at 950 °C, increased open porosity was observed, which decreased the compressive strength of the bricks. Based on the results obtained, the optimum amounts of waste were 5 wt.% sawdust, 10 wt.% compost and 15 wt.% spent earth from oil filtration and marble. These percentages produced bricks whose mechanical properties were suitable for use as secondary raw materials in ceramic brick production.

1. Introduction

Industrial activities, human habits of consumption, and linear process systems are currently generating increasing amounts of waste and by-products. Community policy on waste management is based on minimising the generation of waste by reducing generation at the source, promoting recycling and reuse, and reducing pollution caused by waste treatment by applying clean technologies [1,2]. So, once you have generated these residues, resorted to a series of techniques for reuse. It is the so-called way of the three 'r' recovery, recycling and reuse.

Reuse to take the materials considered as waste and intended for production and consumption processes. However, recycling implies separation and treatment of these materials [2]. Recovery, reuse and recycling can reduce environmental impacts, increase the useful life of the raw materials employed and lower final production costs.

The use of waste and by-product materials in infrastructure development is proven to be economically viable when environmental factors are considered and when these materials meet appropriate performance specifications and standards.

The ceramics sector can incorporate large amounts of waste materials without relevant process modifications [3–6], while taking advantage of the calorific value from waste combustion or incorporating the residue in the internal structure of materials, such that the residue forms part of these materials' matrix and becomes an inert element [7]. It can speak of an energy recovery or a recovery of the waste material. This recovery minimises the impact of the residue on the environment. In some cases, the materials made with residue even achieve better performance than the same material made without the residue.

Sawdust is a waste from the primary woodworking industry. Sawmills have yields between 50% and 55%; only about half of the volume of wood consumed is transformed into products. Proper use of by-products is thus very important. Sawdust is used primarily in thermal processes (biomass), due to its high content of organic matter, and to a lesser extent for livestock and agriculture. Little work has attempted, however, to develop the use of these wastes in the production of building materials [8–11].

Spent earth generated in the production of filtered oil is a significant solid waste. These clays are soaked in oil at a concentration of about 30–50%, so that they approach the risk of spontaneous combustion. They are also valuable as soil amendments, co-byproducts for composting and recycling for the manufacture of cement. The production of compost is the main and most common means of recovering bio-waste through the typical biological treatment of methane and composting as a viable and economical alternative for environmentally sound management of organic residues [12]. The compost is used mainly in agriculture and horticulture because it is rich in organic matter and nutrients.

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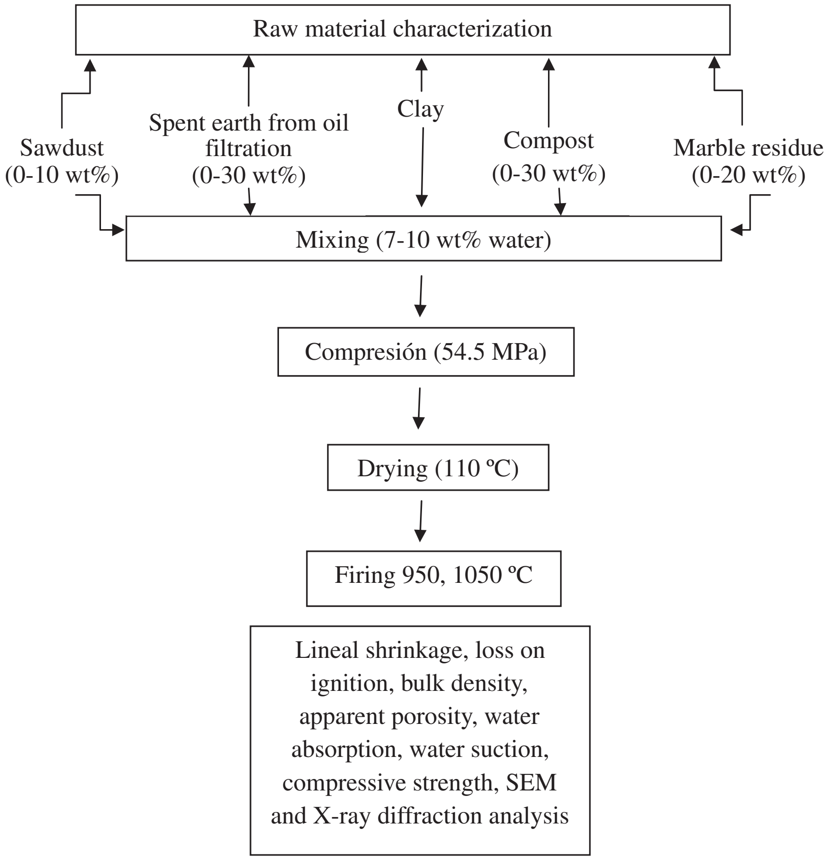

Fig. 1. Experimental scheme.

The incorporation of organic residues in clay as pore-forming agents in ceramics technology has been studied by other authors [8–11,13–23]. The organic nature of these residues requires an energy input to release its calorific power during combustion in the ceramic firing process, enabling energy saving in manufacturing and reducing fuel use. Further, such combustion products give the fired clay a more porous microstructure. This both decreases the clay's density and is expected to improve the clay's thermal insulation capacity. Another way of generating porosity in the clay is by introducing marble residue, which is composed primarily of calcium carbonate. The marble industry generates residues from the accumulation of large quantities of dust and white mud during the process of cutting and polishing the material. Broadly speaking, environmental problems in the marble sector consist of the dumping of residues and mud from the processing industry into public waterways, as well as serious degradation of the urban environment in population centres that house these industries. Attempts are being made to utilise marble wastes in different applications, such as calcium silicates [24], road construction, concrete and asphalt aggregates, and cement or other building materials [25,26].

This paper presents the results of a study designed to evaluate the technological properties of ceramic bricks obtained with the addition of organic (sawdust), organic–inorganic (spent earth from oil filtration and compost) and marble residues used in clayey material as pore-forming agents in ceramic industry.

2. Experimental

2.1. Preparation of the samples

The clay was supplied by a clay pit located in Bailen, Jaen (Spain) and was obtained by mixing three types of raw clay in equal parts: red, white, and black clay. The clay was crushed and ground to yield a powder with a particle size suitable to pass through a 150 μm sieve. Among the wastes used, stand us, spent earth from oil filtration, compost, sawdust and marble were added to the clay in different amounts (Fig. 1) and mixed in a mortar to obtain good homogenisation. To enable comparative results, ten samples per series were prepared for the tests. The necessary amount of water (7–10 wt.% moisture) was added to the samples (with the exception of spent earth from oil filtration, due to its oil content) to obtain adequate plasticity and absence of defects, mainly cracks, during the semi-dry compression moulding stage under 54.5 MPa of pressure, using a uniaxial laboratory-type pressing Mega KCK-30 A. Waste-free mixtures were also made as a reference. Solid bricks with 30 × 10 mm cross sections and a length of 60 mm were obtained. Samples were fired in a laboratory furnace at a rate of 3 °C/min up to 950 and 1050 °C for 4 h. Samples were then cooled to room temperature by natural convection inside the furnace. The shaped samples were designated as C for the bricks without waste and C–*x*W for the mixtures, where *x* denotes the content (%) in the clay matrix and W the waste incorporated (W:SEOF (spent earth from oil filtration); W:C (compost); W:S (sawdust) and W:M (marble).

2.2. Characterisation of brick raw materials

Qualitative determination of major crystalline phases in the clay and ash wastes was achieved using the Philips X'Pert Pro automated diffractometer equipped with a Ge (1 1 1) primary monochromator. The chemical composition was determined by X-ray fluorescence (XRF) using the Philips Magix Pro (PW-2440).The thermal behaviour was determined by thermogravimetric and differential thermal analysis (TGA–DTA) with a Mettler Toledo 851e device in oxygen. The total content of carbon, hydrogen, nitrogen, and sulphur was determined by combustion of samples in O_2 atmosphere using the CHNS-O Thermo Finnigan Elementary Analyzer Flash EA 1112. The higher heating value (HHV) was determined using a Parr 1341 Plain Oxygen Bomb Calorimeter.

2.3. Characterisation of the bricks

Linear shrinkage was obtained by measuring the length of the samples before and after the firing stage, using a caliper with a precision of ±0.01 mm, according to ASTM standard C326 [27]. Water absorption values were determined from weight differences between the as-fired and water-saturated samples (immersed in boiling water for 2 h), according to ASTM standard C373 [28]. The bulk density was determined by the Archimedes method [28]. The water suction of a brick is the volume of water absorbed during a short partial immersion. The test to determine water suction was implemented according to standard procedure UNE 67-031 [29].