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Pressured recycled gypsum plaster and wastes: Characteristics of eco-friendly building components

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HIGHLIGHTS

- Gypsum plaster (commercial – CGP and recycled – RGP) was mixtured with waste.
- Uniaxial loading-pressure was applied to mold the specimens.
- Results show good mechanical performance of CGP or RGP with waste.
- Loading-pressure specimen is a good technique to precast bricks and blocks.

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ABSTRACT

The objective of this paper is to study some characteristics of a component to buildings made with gypsum plaster (commercial – CGP and recycled – RGP), and wastes (red ceramic – RC and porcelain – PW) by loading-pressure. Bricks were prepared with a solid mass composition containing 50% (by weight) of binder, 50% (by weight) of waste, and very small water/dried powder ratio (0.22). Specimens were molded with uniaxial loading-pressure (10 kN) before setting times. Compressive and flexural strengths, porosity, and microstructure were evaluated. The compressive results were in the range of 12.3 and 33.9 MPa, higher than the minimum required by Brazilian Standards to building components (≥2.5 MPa). The low water/solid mass ratio and the uniaxial loading-pressure before setting times contribute to decreasing the porosity, which was shown in the dense microstructure. The obtained results show that these components present a good quality building component.

1. Introduction

Building components production, such as those based in cement Portland and red ceramic, consumes energy and pollutes the environment [1]. The use of wastes on alternative materials for building components can provide products of quality with lower costs and energy consumption [2].

Some studies already reported the feasibility to make composites with gypsum plaster and waste materials [3–6]. Based on these findings, this study used two different industrial wastes in mixtures made with commercial and recycled gypsum plaster: red ceramic waste (RC) and porcelain waste (PW).

Gypsum plaster (calcium sulfate hemihydrate) is a material largely employed in civil construction. It is produced by the calcination of the mineral gypsum (calcium sulfate dihydrate) in low temperatures related to other binders. The gypsum plaster can also be produced from recycling natural gypsum and/or synthetic gypsum, such as phosphogypsum from the production of phosphoric acid, FDG gypsum from power plant flue gas desulfurization units, fluorogypsum from hydrofluoric acid industry and others [7–10]. In the calcination process, the dihydrate loses water to become hemihydrate [11,12]. When the hemihydrate is in contact with water the hydration and the crystallization process occur and the material harden and acquires strength [13].

The gypsum plaster can be considered as a low energy environmental-friendly binder [14]. The calcination temperature for gypsum plaster production is low, in the range of 125 °C – 180 °C, it loses water vapor and the carbon dioxide emissions come from the kiln heat [12].

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A large amount of gypsum plaster waste (GPW) is generated during the production and application of gypsum plaster in civil construction. GPW is a non-inert material with potential to contaminate the groundwater [15]. The sulfate in landfills can be converted to hydrogen sulfide (H_2S) under anaerobic conditions which can cause odor problems to landfill employers or surrounding residents, and also pipe corrosion [16].

GPW can be reused or recycled, having similar performance than the original gypsum plaster [7,17]. GPW calcination demands low energy consumption. Suárez et al. [18] showed that the energy spent on gypsum recycling process is 65% lower than the one consumed to obtain natural gypsum. Camarini et al. [19] showed that when properly calcined, the energy consumption to GPW recycling (447.12 kcal/tonne) is similar to natural gypsum production (439.65 kcal/tonne).

Ceramic materials are produced by the mixture of clay, sand and other natural materials which are fired in the range of 1000 °C – 1250 °C to make bricks and tiles. They represent a large volume of the total construction and demolition wastes generated worldwide [20,21]. Red ceramic waste (RC) is generated during production and using bricks and tiles in buildings. The landfill disposal of RC is still common [21,22]. Only in Brazil, the annual generation of RC is estimated at 6.5 million tonnes/year [23].

Porcelain waste (PW) used in this study comes from electric insulator wastes. Globally, there is a high demand by electric insulator and a large quantity of waste is generated, which is mainly composed of porcelain [24,25]. PW is a dense and hard material, and the correct final disposal is an important issue for producer industries [26,27]. The generation of PW in Brazil is in order of 25,000 tonnes/year, and in Japan, only one industry generated 3700 tonnes in 2015 [28,29].

The use of the wastes as raw materials contributes to the sustainable development and decreases natural resources consumption [30]. RC and PW were already employed in the production of building materials. Studies reported the use of RC as a pozzolan addition in Portland cement and in alkali-activated binder, and as fine and coarse aggregate in concrete [20,28,31,32].

San-Antonio-González et al. [5] reported the feasibility of producing gypsum plaster composites incorporating RC. The authors obtained materials for interior cladding walls with properties (mechanical strength, hardness, and capillary water absorption) that reached the minimum requirements established by Standards to be applied in buildings.

The present work studied some properties of building materials made with commercial and recycled gypsum plasters, RC, and PW by loading-pressure. While previous studies reported the production of building materials made with commercial gypsum plaster and wastes, the present paper tested the use of wastes also with recycled gypsum plaster. The materials were produced by the application of uniaxial loading-pressure before the initial setting and some properties, such as compressive and flexural strengths, porosity, TG/DTA, and microstructure were investigated.

2. Materials and methods

2.1. Materials

The materials used in the study were commercial gypsum plaster (CGP), recycled gypsum plaster (RGP), RC, PW, and water from the municipal supply.

RC used in the study is composed of grounded red ceramic tiles waste. The material was used without any pretreatment. PW was obtained from a Brazilian insulator industry. The material was crushed, milled until obtaining a fine powder, sieved (95% passed on a 45 μm sieve), homogenized, and stored in a sealed container.

CGP was used without any pretreatment. RGP was obtained from GPW generated by local construction sites. GPW was collected, sun-dried to remove the moisture, and manually crushed with a rubber hammer. Thereafter, the material was grinding through a hammer mill crusher with 80% of the passing particles lower than 0.297 mm. The resultant powder was homogenized and calcined in a stationary kiln at a constant temperature (150 °C ± 5 °C) for 1 h. After calcination, the powder material was homogenized again and RGP was ready to be used.

Table 1 shows the chemical composition and the physical characteristics of CGP, RGP, RC, and PW. Figs. 1 and 2 show the particle size distribution and the X-ray diffraction (XRD) patterns of the materials, respectively.

The chemical composition was obtained by X-ray Fluorescence (XRF). The analysis were conducted with a wavelength dispersive X-ray spectrometer (Shimadzu XRF 1800). Particle size distribution and bulk density were made according to [33], and specific gravity according to [34].

XRD patterns were collected in a Philips Analytical X-ray (model X'Pert-MPD) with Cu-Kα radiation (1.54060 Å), 40 kV, 40 mA, and in the 2θ range of 10–60°. Inorganic Crystal Structure Database (ICSD) was used to identify the crystalline phases.

The chemical composition of CGP and RGP did not show significant differences and the main compounds are SO_3 and CaO. The wastes main compounds are SiO_2 and Al_2O_3. After the recycling process, the chemical characteristics of gypsum plasters are similar to the commercial ones, with changes in some physical properties

Table 1
Compositions and physical properties of CGP, RGP, RC, and PW.

Elemental composition (%)	CGP	RGP	RC	PW
SiO_2	0.15	0.15	63.50	71.71
Al_2O_3	0.08	0.05	12.06	13.62
K_2O	0.05	0.04	6.21	5.47
Fe_2O_3	0.05	0.02	10.94	2.06
TiO_2	–	–	1.49	0.57
MgO	0.02	0.06	1.55	0.24
P_2O_5	0.71	0.74	0.89	0.81
CaO	27.04	27.80	1.18	1.59
Na_2O	0.54	0.80	–	0.46
SO_3	60.79	62.07	–	–
LOI	10.33	8.00	1.66	3.00
Others	0.24	0.27	0.52	0.47
Physical properties				
Specific gravity (kg/m^3)	2610	2570	2650	2550
Bulk density (kg/m^3)	648	280	1120	1097

CGP = commercial gypsum plaster, RGP = recycled gypsum plaster, RC = red ceramic waste, PW = porcelain waste

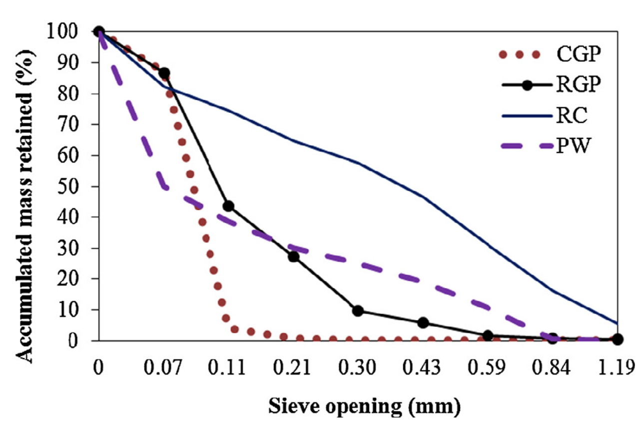

Fig. 1. Sieve analysis.