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Uso de escória de cobre na fabricação de argamassas de cimento

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Resumo

Estudou-se a utilização da escória de cobre de uma fundição do Chile na fabricação de argamassas de cimento. A escória foi caracterizada através de análise química, mineralógica e granulométrica. Também foram usados diferentes padrões para se conhecerem alguns parâmetros importantes da escória e se fazerem os ensaios de compressão e de flexão das argamassas. Os resultados mostraram que as argamassas feitas com escória de cobre apresentaram maior resistência à compressão e à flexão que as preparadas com areia. O estudo conclui que esse resíduo metalúrgico poderia ser utilizado na construção civil.

Palavras-chave: Escórias de cobre, argamassas, compressão, flexão, construção civil.

Abstract

The use of a Chilean copper smelter slag in the manufacture of cement mortars was studied. Copper slag was characterized from the chemical, mineralogical and size distribution point of view. In addition, different Chilean standards were used to determine some important parameters of the waste and to perform compression and flexural assays of the cement mortars. The results obtained showed that the mortars manufactured with copper slag present a higher resistance to compression and flexural than those manufactured with river sand. It is concluded that this metallurgical residue can be used in civil construction.

Keywords: *Copper slag, mortars, compression, flexural, civil construction.*

1. Introduction

Copper slag is a massive metallurgical residue obtained from the transformation of copper ore concentrates into metallic copper in the smelters (Figure 1). Slags are deposited in landfills that occupy large areas of land. Their chemical composition is rich in iron, silicon and aluminium oxides and in their mineralogical composition, the presence of fayalite and magnetite, among other compounds is common (Gorai, Jana, Premchand, 2003). The main environmental impact produced by slag disposition is a change in land use and the visual pollution of the landscape (Figure 2). On the other hand, under certain weather conditions, leaching can occur, depending on the characteristics of the solution, the composition, and the final crystalline structure of the solid slag. (Demetrio et al., 2000).

It is estimated that in the copper industry, for every ton of metallic copper production, approximately 2.2 tonnes of copper slag is generated and in the world, about 24.6 million tons of slag is produced annually (Gorai, Jana, Premchand, 2003). In Chile, there are seven copper smelters: Hernán Videla Lira, Vetanas, Chagres, Potrerillos, Caletones, Chuquicamata and Altonorte. These metallurgical centers produced 2,360,000 metric tons of copper slag in the year 2002 (Goonan, 2005), leaving this waste deposited indefinitely as a hard floor, without current industrial utility. However, global experiments for the use of copper slag have been going on in various sectors of production and the results have been published with very good prospects. In particular, there is the use of this metallurgical waste in the construction industry, where one of the studied applications is its use as a substitute for aggregates, both in cement mortar and concrete (Goñi, Lorenzo, Sagrera, 1994), (Resende, Cachim, Bastos, 2008), (Al - Jabri et al., 2006), (Shi, Meyer, Behnood, 2008), (Wu, Zhang, Ma, 2010a), (Wu, Zhang, Ma, 2010b), (Moura et al., 1999). In this context, various worldwide experiences point to the appropriate use of the copper slag in the manufacture of concrete and cement mortars, generating a recycling opportunity for what would otherwise be massive metallurgical liabilities.

This article describes an experimental study performed to determine possibilities for the use of copper slag as a substitute for the traditional sand in the manufacture of cement mortar. For this purpose, the slag from a Chilean copper smelter was used.

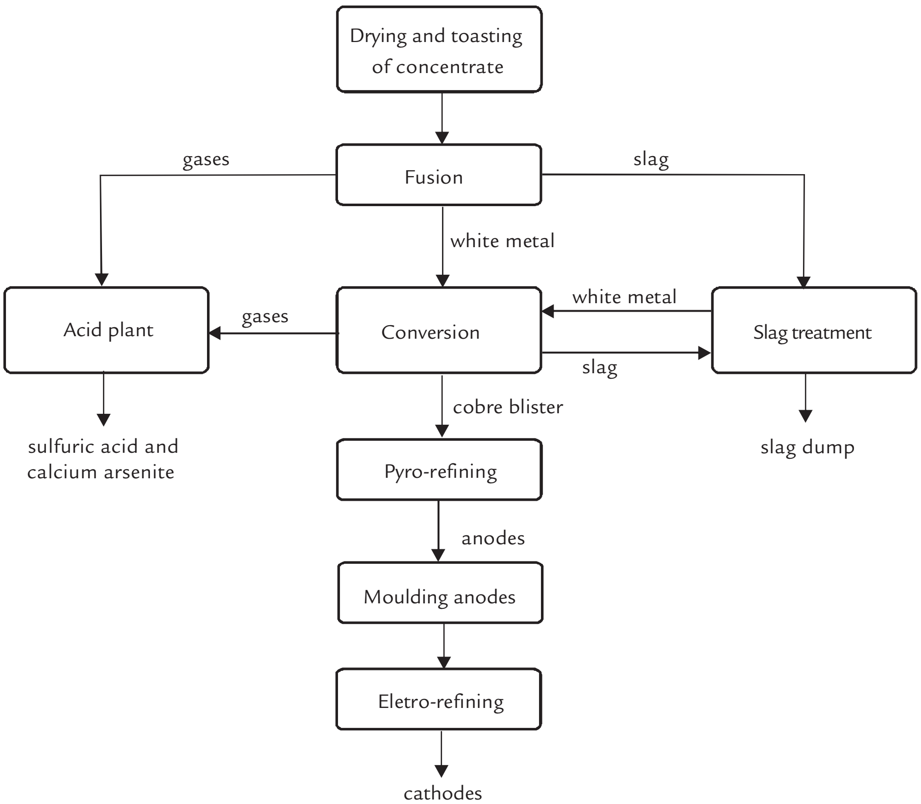

Figure 1
Pyrometallurgical and electrometallurgical processes for the production of copper cathodes.

Figure 2
Copper slag deposit minimizing the cultivation area in the Valley of Copiapó, Atacama Region (courtesy Google Maps).

2. Materials

Having been solidified by slow outdoor cooling, discarded copper slag from the Hernán Videla Lira smelter, located in the Atacama Region (Chile), was used, Daily, the smelter pours 600 tons of slag containing 0.8% of copper into the designated open-air area. Samples were prepared with cement belonging to the puzolanic class, current degree, according to standard NCh 148, Of.1968 (INN, 1968), containing 67% of clinker, 30% of pozzolana and 3% of gypsum approximately, with a Blaine Index in the order of 3900 ± 150 cm^2/g. Shot sand purchased from a supplier of Copoiapó River aggregates and used as the fine aggregate. Drinking water supply was used in the preparation of the samples.

3. Methods

Design of mixing and preparation of the samples in the laboratory

The copper slag and river sand employed were characterized in the Material Strength Laboratory of the Universidad de Atacama and in the Cement Mixture Laboratory of INACESA, a company located in Antofagasta. Test tubes of mortar were built according to the standard NCh2260. Of1996 (INN, 1996a) in the form of prismatic bars having dimensions of 40 x 40 x 160 mm (width, height and length) with mixtures of cement, water and sand. The reference mortar was manufactured using only river sand (100%) as the agglomerate, while the mortar of this study was manufactured with only copper slag (100%) as the agglomerate. Constituents were weighed separately and then in the lab, were mixed in an electric mortar mixer to ensure homogeneity. This mixture was poured into metal molds and subsequently compacted according to the Chilean standard NCh158. Of1967 (INN, 1967). Within 24 hours, the molds were removed from the hardened mixture which formed the prismatic bars and underwent a process of "curing", which consisted of immersing them in water saturated in lime at a temperature of 23°C until it was the time for their compression and bending test, according to Chilean standard NCh158.Of1967 (INN, 1967).

Compression and bending tests

After curing, each sample was identified, measured and weighed with a scale. Nine test tubes were tested for compression and nine for bending. For each of these tests, three of tubes had been cured for 3 days, three for 7 days and three for 28 days. The compression and bending tests were carried out according to the Chilean standard NCh158.Of1967 (INN, 1967). All tests were conducted on a "Controls" brand hydraulic press.

4. Results and discussion

The chemical composition of the main components of the copper slag is presented in Table 1. Notice that the major components are Iron (Fe) and Silica (SiO_2).

Mineralogical analysis to the copper slag showed the presence of the following phases: 51% of 2FeO. SiO_2 (fayalite), 10.2% of $2MgO.SiO_2$ (magnesium fayalite) and 38.8% of magnetite. On the other hand, the copper slag presented a real density of 3,817 (kg/m^3), by which it is considered a heavy aggregate.

The granulometry of the copper slag sand was analyzed taking into consideration the granulometric requirements according to Chilean standard NCh163.Of1979 (INN, 1979). In all analyzed cases, the slag sand presented an excess in size fractions of 0.6 mm, 1.18 mm and 2.36 mm, ultra-passing the limits imposed on sand used as an aggregate in construction and causing the distribution curve to be left out of the graph (Figure 3). However, the present study was conducted without modifying the initial grain size of slag.

Table 1
Chemical composition with the main components of the copper slag.

Chemical Composition	Cu	Cr_2O_3	Fe_T	Fe_3O_4	SiO_2	Al_2O_3	CaO	MgO	Cl	Pb
(%)	0.75	0.05	41.45	5.14	27.89	2.91	2.10	0.88	0.12	0.11

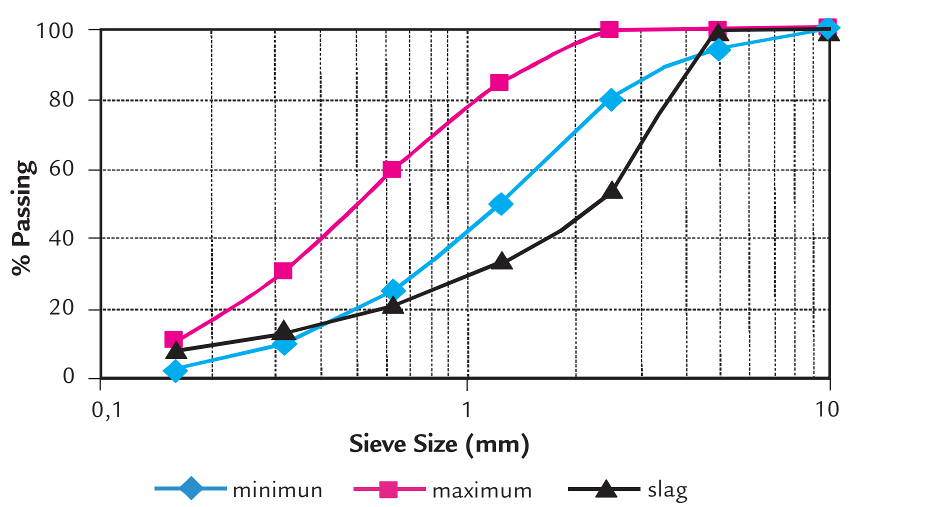

Figure 3
Granulometric requirements and grading distribution of copper slag.

Table 2 presents the compressive strength results for mortars prepared with copper slag and river sand for 3, 7 and 28 days of curing times.

Table 3 shows the results of the bending resistance with mortars prepared with copper slag and river sand, for curing times of 3, 7 and 28 days.

It can be seen from Tables 2 and 3 that the compressive strength of the mortar using copper slag is higher than the values achieved in mortars using river sand. This was proven for 3, 7 and 28 day curing times: the mortars with copper slag presented higher compressive strengths, 114%, 66% and 44%, respectively, in relation to the resistance achieved in mortars using river sand. Also, it was found that the slag mortars that had curing times of 3, 7 and 28 days presented bending resistance superior to 97%, 44% and 35%, respectively, when compared to the bending resistance of mortars using river sand. The high resistance differences at an early curing age (3 days) suggest that this material may be in used warm geographical areas and/or in works requiring rapid hardening of the mortar.

Time (days)	Resistance to the compression of river sand mortars (MPa)	Resistance to the compression of copper slag mortars (MPa)
3	13.75	29.38
7	22.58	37.38
28	32.71	47.08

Table 2
Compressive strength of mortars prepared with 100% river sand and 100% copper slag.

Time (days)	Resistance to the compression of river sand mortars (MPa)	Resistance to the compression of copper slag mortars (MPa)
3	0.19	0.38
7	0.31	0.44
28	0.37	0.50

Table 3
Resistance to the bending of mortars prepared with river sand and 100% copper slag.

5. Conclusions

The results obtained in this study indicate that the use of copper slag in mortars as a substitute material for river sand gives options for the employment of this massive waste as an alternative material that is environmentally sustainable and appropriate for the construction industry.

Mortars manufactured with copper slag presented greater resistance to both compression and bending as compared to mortars manufactured with river sand. This was verified at different curing ages: 3, 7 and 28 days, and highlighted the importance of the increase in initial resistance, which would recommend its use in warm climates and/or in situations that demand quick hardening of the mortar.

6. Acknowledgements

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