The Use of Red Mud and Kaolin Waste in the Production of a New Building Material: Pozzolanic Pigment for Colored Concrete and Mortar

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Abstract

The state of Para is one of the greatest producers of mineral substances in Brazil. Kaolin for paper coating industry and bauxite for alumina and aluminium production are amongst the most important commodities. The latter is responsible for the generation of red mud, a well-known residue from Bayer process. The kaolin processing plants are also responsible for the generation of large amounts of wastes, in this case, very fine-grained kaolinite (white mud). The research aimed to find a final destination for such residues by developing new building materials. The proposed material is a pozzolanic pigment produced through calcination and grinding of mixtures of red mud and kaolin waste. The pozzolanic pigments provided increased mechanical strength and color stability of the colored mortars relative to the inert pigment. The pozzolanic characteristics of the pigments reduced the leaching of the mortars. The new material has proven to be promising in its application as an innovative construction material, with the possibility of opening a market that has not been explored in Brazilian civil construction: the colored mortars and concrete.

Keywords: Red mud, kaolin waste, colored concrete, pozzolanic pigment.

1. Introduction

The state of Pará is one of the most privileged regions of the planet in terms of exploitation of mineral resources. The mining projects in Pará stand out because of the quality of the product, the commercialized values and the magnitude of the production volumes, which makes them also responsible for the generation of significant quantities of waste or by-products released and deposited in the environment. Among the most diverse types of residues generated from its intense mineral activity, the production volume of the kaolin waste (KW), due to the extraction and processing of kaolin, and the red mud (RM) of the Bayer process to obtain alumina from bauxites. It is estimated that the deposited amounts of KWand RM since the implantation of kaolin mills and Alumina do Norte do Brasil SA (ALUNORTE) are 15 and 60 million tons, respectively.

The KW has excellent technical characteristics, which has been demonstrated by the various researches, indicating the application potential not only in the field of building, but also in the refractory and advanced ceramic industries [1-7]. It consists essentially of extremely fine kaolinite, presents excellent uniformity and easy handling. All these requirements are excellent for the production of a highly reactive pozzolan from the calcination and grinding of pure kaolinite clays with very low inert minerals called metakaolin or metakaolinite.

RM itself would not be a toxic waste if it were not for its causticity, so much so that the United States Environmental Protection Agency does not classify it as a hazardous waste [8]. However,

other researchers consider it to be toxic precisely because of the high alkalinity and ion exchange capacity, which constitute a high risk to neighboring populations [9-10]. The chemical and mineralogical characteristics of RM impose difficulties to its use due to the variety of minerals present. In general, RM consists of a complex assembly of minerals ranging from those not dissolved in the process such as aluminum oxides and hydroxides (gibbsite, boehmite e diaspore), the iron oxides and hydroxides (hematite e goethite), rutile, anatase, calcite, dolomite, kaolinite, besides the neo-formed ones as sodalite and cancrenite and others that are in the form of traces as the oxides of V, Ga, P, Mn, Mg, Zn, Th, Cr e Nb.

In addition to the trend in the world aluminum industry for the densification of waste in order to reduce the generated volume of RM, many attempts have been made to take advantage of it instead of simply depositing it because of the high costs of RM disposal in the residue disposal area (DSR). However, the vast majority of the studies did not find a satisfactory application from the economic point of view [11]. Among the various applicability of RM, it is important to highlight the direction of the efforts for the use in Construction as a raw material for the manufacture of building materials. The feasibility of such a solution would be of threefold benefit, since the large-scale consumption of building materials could substantially eliminate or mitigate the problem of waste disposal; would add economic value to RM and would be easier to deploy on a universal scale.

Perà et al [12] claim that calcined RM could be used to produce colored concrete as a low-cost pigment compared to conventional pigments. In addition to the economic aspect, it presents some other technical advantages such as the elimination or reduction of efflorescence, common pathology in concrete structures and that is extremely harmful to concrete and colored mortars because it is responsible for the appearance of efflorescence on the surface, substantially damaging the color of the material surface [13]. Another positive aspect would be the possibility of being used in larger percentages, without loss of resistance, which commonly occurs with conventional inorganic pigments, which are inert.

A disadvantage of the use of RM as a building material would be free or exchangeable sodium present in sodalite, which could render its use in Portland cement based products unreliable due to the activation of alkali-aggregate reactions and the crystallization of salts on the surface (efflorescence). Due to this possibility, the present paper starts from the hypothesis that the combined calcination of RM with KW, in addition to increasing the pozzolanic activity, the exchangeable sodium present in the sodalite can be stabilized by solidification (S / S) when the occurs the formation of the structure of silicates and calcium aluminosilicates from the cement hydration and the pozzolanic reactions between metakaolinite and Portland cement.

Another advantageous aspect of the combined use of KW and RM are the distances between the residue disposal areas. Both residues are generated in the municipality of Barcarena, within a radius of 5 km between the DSR of ALUNORTE and the sedimentation ponds of Imerys. The aim of this article was to evaluate the technical feasibility of the pigments from the RM and KW mixtures by investigating their effect on the properties of colored mortars such as compressive strength, color stability and, finally, to contribute to an environmental assessment of RM by conducting leaching tests on the pigments and mortars that incorporated these pigments.

2. Experimental

2.1. Raw materials and pigments

The raw materials used in the research were KW from Imerys and RM from ALUNORTE. The pozzolanic pigments were produced from calcination at 800 ºC and milling of three distinct proportions of RM and KW, besides the individually calcined RM (CRM). The commercial

4. Conclusions

The incorporation of pozzolanic pigments from RM and KW mixtures has provided substantial increases in compressive strength compared to commercial BF pigments, which is extremely advantageous for the case of colored concrete flooring.

The pozzolanic pigments reduced the concentrations of sodium leachate in the mortars due to the presence of metakaolinite, which through the pozzolanic reactions promotes the stabilization of the chemical element by solidification.

As a result of this mitigation of sodium leaching, pozzolanic pigments also provided greater color stability to mortars compared to commercial pigment BF.

The pozzolanic pigments showed superior behavior to the commercial pigment in terms of mechanical resistance, reduction of sodium leaching and greater color stability due to the reduction of efflorescence. Only the color intensity was lower, however, this aspect can be mitigated with greater incorporations of pozzolanic pigment without prejudice to the mechanical properties.

In summary, the results demonstrate the promising character of the RM-KW mixtures for the production of pozzolanic pigments as well as mineral admixture for pozzolanic cements of excellent durability and mechanical behavior.

5. References

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