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Research paper

Study of recycling of carbon tailings from Portland cement pro-duction

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Abstract

In the clinker Portland production process, rotary kilns burn fuels to reach temperatures as high as 1450 °C. In the Mato Grosso do Sul State, the most common fuel used in such kilns is grounded charcoal. After the grinding steps, charcoal is sieved, and the re-tained material is discarded as tailings. Despite such materials have some carbon matter in its composition, it is a high ash content material. This work is based on the hypothesis that, during the grinding of the material, organic compounds would break in finer particles since they show lower abrasive strength. Thus, ash materials would remain in the coarser particles. The goal of the work is to evaluate the viability of the use of charcoal fines in Portland cement to reuse the material in clinker Portland production. To achieve the proposed goal, fines were fractionated in different particle sizes. Each size fraction was characterized regarding its ash content, proximate analysis, and calorific value. The results allowed to relate size fraction with ash content and calorific value. The results revealed that coarser size fractions (retained in 0,500 mm) presented lower ash content and calorific value. Furthermore, such size fractions correspond to 24,04 % in mass of material.

Keywords: *Carbonous Materials Recycling; Charcoal Tailing; Reuse of Charcoal Fines.*

1. Introduction

The Portland cement production consists of steps that aim to obtain a material that, when mixed with water, results in an agglomerant. Those characteristics make the Portland cement the main component of the concrete. In the construction sector, the concrete is used to build roads, bridges, water supply systems, sewage treatment, schools, hospitals and dwellings [1].

The Portland cement production may be divided in two main steps: the production of clinker (an intermediate product) and the Portland cement production, throughout the use of clinker. The Figure 1 shows a flowsheet of cement production.

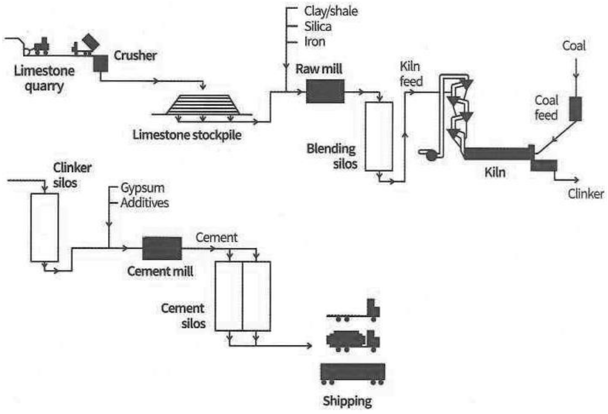

Fig. 1: Flowsheet of Cement Production Process [1].

The clinker production starts with the limestone mining. The ore is crushed and mixed with clay. To adjust the charge composition, iron ore, sand and bauxite may also be added in the charge mix. The materials are added to a grinding step, in which the particle size is lowered, and the charge is homogenized.

The materials are then heated in pre-heating towers at temperatures around 800 ˚C. During this process, the charge is dried, and the limestone is calcined, according to the following reaction (Equation 1) [1]. The product of the pre-heating step is changed in a rotary kiln, which has a main torch that reaches a temperature of 2.000 ˚C.

$$CaCO_3 + heat = CaO + CO_2 \quad (1)$$

Within the furnace, the charge reaches temperatures as high as 1.450 ˚C. At such temperatures, the charge undergoes an incipient melting and it is then quenched. The result of this process is called clinker Portland. To the clinker, depending upon the kind of cement that is produced, slag of metallurgical processes, fly ashes, pozzolans and limestone filler may be added to the charge. The product of the grinding of the mixture is called Portland cement [1].

In the rotary kiln, a broad range of materials are used as fuel. Therefore, the cement production is considered a sustainable process, since it uses materials that are considered waste to other industries to produce the clinker.

In the cement producers of the state of Mato Grosso do Sul in Brazil, the main fuel materials used in the Portland cement production are coke, charcoal (both of them as fines) and ground tires. The charcoal fines may have two sources: products of the degradation process during transportation and storage or products of a grinding process.

The product of the charcoal grinding, before being used as fuel, is sieved. The coarser fraction has as characteristics the high ash content, low carbon content and calorific value. Thus, the use of this fraction is the subject of this work. The use of such materials in the Portland cement industry may minimize the waste generation of the industry. Furthermore, the use of this material may decrease the fuel consumption within the plant.

Thus, this work aims to explore the differences between the charcoal and ashes materials in the brittleness and abrasion strength [2]. Based on this hypothesis, it is believed that by separating materials into different size ranges, materials with higher carbon contents can be obtained.

There is literature available regarding alternative materials and wastes as fuel in the clinker production process [3 - 6]. The references point to the use of such materials being a promising alternative to lower the fuel costs [4]. Moreover, the use of waste materials as fuel in clinker production is also environmentally advantageous, since it avoids the deposition of such materials as tailings [5].

The use of the charcoal courses is a particularly interesting alternative as the material does not have hazardous elements in its composition [6]. Thus, in addition to its high calorific value, when compared with other alternative fuel material in clinker production [7], the use of charcoal coarse material presents low environmental risk.

Lastly, the work is based on the hypothesis that, during the process of grinding the differences in brittleness and abrasion strength resulted in different size distribution of carbonous material and charcoal. The different compositions of size ranges in comminution were previously observed by Brandão et al. [2]. Furthermore, the phenomena mentioned by Brandão et al. [2] was observed in carbonous materials by de Jesus [8]. Thus, throughout the data presented, it is believed that such differences may be explored to obtain a material with the carbon content high enough to be recycled in the clinker production process. Therefore, it is necessary to validate the hypothesis previously stated. The main goal of the work is to evaluate the viability of recycling of charcoal tailings from the Portland cement production process to reutilize it in the process itself.

2. Materials and methods

The experimental procedure was performed in the Materials and Metallurgy Laboratory of the Federal Institute of Mato Grosso do Sul in Corumbá/Brazil. The methods were summarized in the flowsheet displayed in Figure 2. The samples of charcoal tailings were provided by an industry located in Mato Grosso do Sul state.

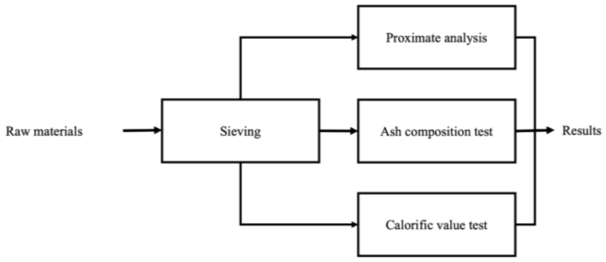

Fig. 2: Flowsheet of the Experimental Procedure.

2.1. Sieving

The samples were homogenized, fractionated and sieved in different sizes. The sieves used in the work were: 2,0, 1,0, 0,500, 0,250 and 0,075 mm. Each of the size ranges were then homogenized and sampled to be characterized.

2.2. Ash chemical composition tests

The ash chemical composition tests were performed by X-ray fluorescence technique (XRF). The XRF tests were carried out by a Shimadzu X-ray fluorescence spectrometer, model EDX-720. The tests were performed to determine the elemental composition of the ash constituents.

2.3. Proximate analysis

The proximate analysis was performed to assess the moisture, ash, and volatile matter content and, consequently, the fixed carbon of the samples. The tests were performed according to the ASTM D3172-13 standard.

2.4. Calorific value measurement

The calorific value determination was performed according to the ASTM D5865 procedure. The tests were performed in triplicate. To test the calorific value a IKA, model C200, calorimeter was used.

3. Results and discussion

Throughout the tests presented in the proposed experimental procedure, information regarding size distribution of the material was obtained. Table 1 presents the result of the particle size analysis.

Table 1: Particle Size Analysis of Charcoal Tailings from Portland Cement Production

Sieve size [mm]	Passant [%]	Retained [%]	Cumulative retained [%]
2,00	90,36	9,64	9,64
1,00	84,64	5,72	15,36
0,500	75,96	8,68	24,04
0,250	36,84	39,12	63,16
0,075	2,09	34,75	97,91
Bottom	-	2,09	100,00

Through the results presented in Table 1, the data was plotted in the graph of Figure 3. Figure 3 presents the size distribution of charcoal tailing material. The material presents a high percentage of material passant in the 0,500 mm sieve. This corresponds to 75,96 % in mass of the material.

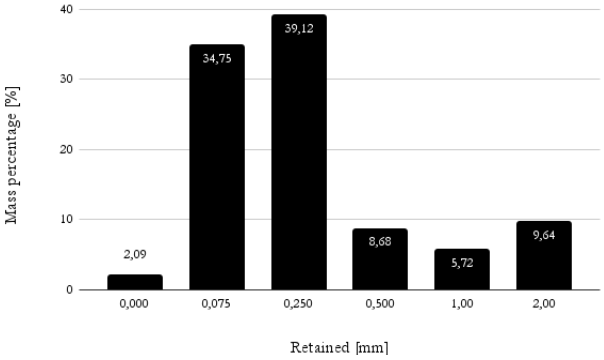

Fig. 3: Particle Size Distribution of Charcoal Tailing Material.

The results regarding ash, volatile and fixed carbon content and calorific value are shown in Table 2. As pointed out in the table, those parameters were measured for each size range to allow the search for high fixed carbon and low ash content values within the different size ranges.

Table 2: Proximate Analysis and Calorific Value of the Charcoal Tailing from Portland Cement Production. Note: Ash – Ash Content (Dry Basis); C_{fix} – Fixed Carbon; CV – Calorific Value

Passant [mm]	Retained [mm]	Ash [%]	Volatile [%]	C_{fix} [%]	CV [cal/g]
-	2,00	20,38	39,51	40,11	4521
2,00	1,00	17,99	35,88	46,13	5649
1,00	0,500	22,08	23,14	54,78	2996
0,500	0,250	90,37	8,08	1,55	917
0,250	0,075	86,29	8,26	5,45	915
0,075	0,000	41,05	35,18	23,77	3677

Figure 4 presents the results regarding ash content, on a dry basis. The results pointed out that lower ash content values are present in the coarser size ranges. The material retained in the 0,500 mm (and passant in 1,00 mm) sieve has 22,08 % ash content. The calculated ash content in the accumulated retained in 0,500 mm sieve is 20,43 % and corresponds to 24,04 % in mass of material.

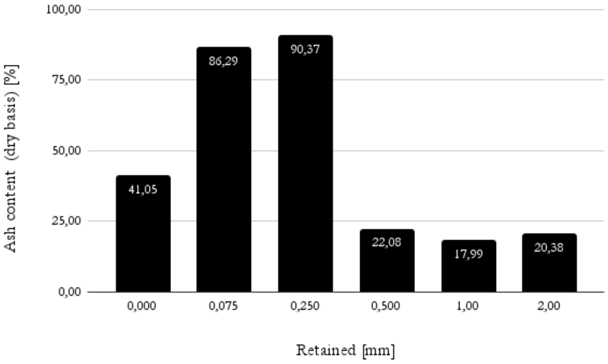

Fig. 4: Ash Content (Dry Basis) Distribution in the Different Size Ranges.

Figure 5 presents the fixed carbon results. The results showed higher fixed carbon content in coarser fractions. Again, the fraction retained in 0,500 mm (and passant in 1,00) presented the best result, higher fixed carbon content, 54,78 %. The calculated fixed carbon of the accumulated retained in 0,500 mm is 46,08 %.

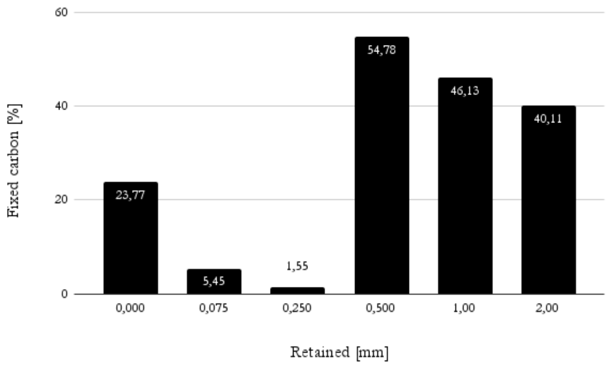

Fig. 5: Fixed Carbon Content Distribution in the Different Size Ranges.

Figure 6 shows the results on the calorific value of the samples in the different particle size ranges. The results follow the trend of that the higher fixed carbon content gives the higher calorific value. Thus, the coarser particle size ranges (accumulated retained in 0,500 mm sieve) presented the higher calorific value. It is also important to highlight the finer size fraction (passant in 0,075 mm) which also owns high calorific value, however, a very low amount of material (2,09 %, in mass) and with many challenges to recover such a fine material in dry beneficiation processes. Thus, the recovery of the material retained in the 0,500 mm size fraction owns a calculated calorific value of 4239 cal/g.

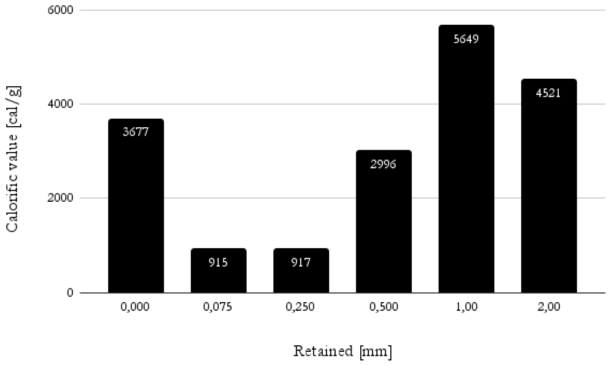

Fig. 6: Calorific Value in the Different Size Ranges.

Table 3 presents the data on the chemical composition of the studied material. The main chemical compounds present in the material were SiO_2, Fe_2O_3, CaO and Al_2O_3. Even though these compounds are considered contaminants of the charcoal, they are purposely added to the Portland cement charge. Thus, the presence of such compounds may be compensated by the mass balance of the charge mixture composition.

Table 3: Chemical Analysis of the Studied Charcoal Tailings, Performed by X-Ray Fluorescence Method

Retained [mm]	Compound [%]								
	SiO_2	Fe_2O_3	CaO	Al_2O_3	TiO_2	MnO	K_2O	P	S
2,00	13,5	37,2	36,5	5,3	0,6	1,0	2,0	0,6	3,3
1,00	14,3	25,0	44,1	6,9	0,9	1,3	3,0	0,6	3,9
0,500	46,1	28,0	14,1	8,3	0,5	0,5	1,3	0,2	0,9
0,250	75,3	4,9	9,3	6,7	0,5	0,1	1,1	0,4	1,8
0,075	64,5	13,3	11,0	6,8	0,8	0,2	1,4	0,4	1,8
0,000	17,5	46,1	26,7	5,8	1,1	0,4	1,2	0,2	1,1

The obtained results indicate that it is possible to recover the material retained in the 0,500 mm sieve. This fraction presents low ash content and higher fixed carbon content as well as a high calorific value. As previously presented, the use of the coarser fractions of the material would allow it to recover 24,04 % in mass of material. As result, the material retained in 0,500 mm sieve had a 20,43 % ash content, 46,08 % fixed carbon content and a calorífico value of 4239 cal/g.

There is also another promising particle size range which is the passant in 0,075 sieve which presents an ash content of 41,05 % and a calorific value of 3677 cal/g. The high calorific value provides recycling potential. However, the small particle size may turn the operation of classification of such materials challenging due to the technologies available to perform the sieving process.

Lastly, the study reveals the existence of ash and fixed carbon content gradients through the different particle size ranges. Those differences allow the recovery of a significant part of the material, around 24 %, producing a material with low ash content and high calorific value to be recycled in the clinker Portland production.

4. Conclusion

The study revealed the feasibility of the recycling of charcoal tailings from clinker production. For that, the particle size range must be the retained in 0,500 mm sieve which is around 24 % in mass of the studied material. The resultant material owns an ash content of around 20 %, fixed carbon content of around 46 % and calorific value of around 4239 cal/g. Despite the size range passant in 0,075 mm had low ashes and high fixed carbon and calorific value it is not possible to recycle it due to the unavailability of an industrial process to separate such size range.

Acknowledgement

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