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Process and Characterization of By-Product Obtained from Kraft Paper Packaging Contaminated with Portland Cement

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Abstract

Packaging contaminated with Portland cement, which is not easily recyclable and has a high cost and environmental impact for processing, is discarded in large quantities by the relevant civil construction sector. Using available literature, a method was developed to transform packages contaminated with Portland cement into a macroscopic by-product, through hydrolysis in sodium hydroxide (NaOH). The results demonstrate that the process can be sustainable for the disposal of bags contaminated with cement, which also showed an average loss of almost 0.1% of Portland cement per bag. Among other characteristics, the by-product obtained has an average density of 0.45 g/cm³ and most of it has a granulometry of less than 0.5 mm, facilitating handling and enabling reuse. This method is capable of including almost 6,000 bags of cement in a volume of 1 m³.

Keywords: Cement bag • Composites • Solid waste

Introduction

In Brazil alone, more recent data (SNIC, 2021) indicate that Portland cement production reached 61 million tons in 2020, where 66% of this was bagged. Normally this amount is distributed in bags of 25 or 50 Kg. This production cycle causes several environmental impacts such as: consumption of natural resources, CO_2 emissions and disposal of waste such as the packaging itself contaminated with Portland cement.

Based on different literatures, reuse technologies can evolve, including a proposal based on the experiments by Fengel and Wegener, where, according to studies, microfibrils swell in cellulose when subjected to alkaline solution, This is a process that takes place in a short period of time. In sodium cellulose, formed after reaction with alkaline solutions, sodium hydroxide (NaOH) is generally used, with concentrations above 20%. The swelling observed by electronic microscopy, with NaOH concentrations between 0 and 15% (Figure 1).

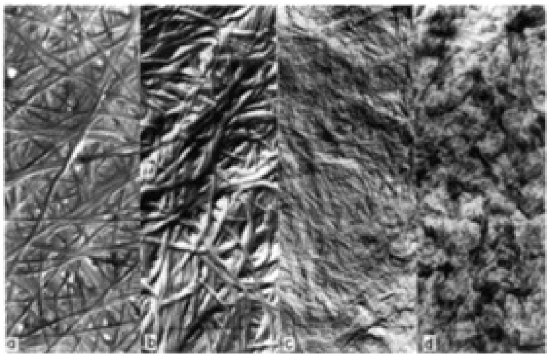

Figure 1. Cellulose (a) Pure; (b) 10% NaOH; (c) 12% NaOH; (d) 15% NaOH - Fengel and Wegener.

Cellulose, after swelling, can be hardened by the effect of Portland cement residues, causing physical changes, including establishing a new material that can offer benefits in other processes, within the characteristics defined by Callister WD [1] for new materials. This work was proposed based on the evolution of several previous experiments carried out by the research group with kraft paper bags contaminated with Portland cement.

Methods

Considering the experience of Fengel and Wegener and the characteristics of Portland cement after the action of water, five square pieces of kraft paper, with a side of approximately 5 cm (Figure 2), cut from the inside of a Portland cement package, were immersed for 2 hours in an aqueous solution, containing concentrations of 0%, 5%, 10%, 12% and 15% of NaOH as solute (Figure 3), as shown in Table 1 [2] (Figures 2 and 3, Table 1) .

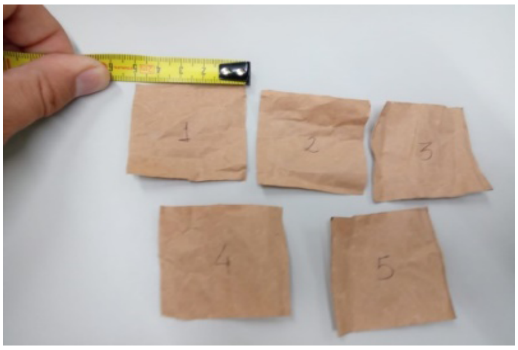

Figure 2. Kraft paper samples contaminated with Portland cement.

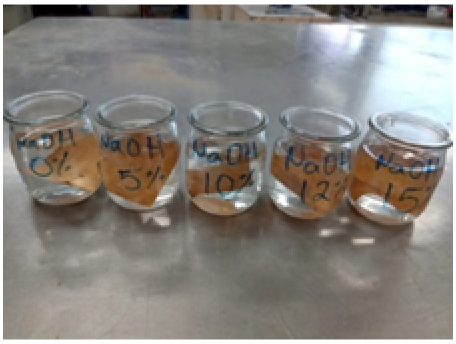

Figure 3. NaOH concentrations.

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The masses in this research were checked on a Gram FH 200 scale with a precision of 0.1 g. Thus, the samples with paper were decanted, subjected to a temperature of 100°C in a Memment UM 4JD oven and observed during the period of 12, 24 and 48 hours, where each dehydrated sample was evaluated for its ease of breaking during drying. The concentration that left the sample breaking more easily and less time in the oven was considered optimal. The optimal concentration was established and detailed.

Using the concentration considered optimal and the respective drying time in the oven, three more samples went through the same process, one of which was made of kraft paper similar to those in the cement packaging and two were taken from the cement packaging themselves, removing all residue by washing with water and sponge, where the effectiveness of the action of cement residues in this process could be evaluated. Thus, three packages of the 25 Kg type had the cement waste found at the bottom (Figure 4) weighed and returned. The packages with residues impregnated in the paper were also weighed and submitted to the same proportion of the solution that was considered optimal and respective drying. Subsequently, already in a brittle form, they were crushed in a Moulimex blender with 4 blades and 300W of power, where each package generated a mass quantity of the by-product (Figure 5), with a small part in the form of the by-product without low granulometry on account deficiency of the effect of NaOH or little Portland cement residue (Figures 4 and 5).

Table 1. Breakdown of NaOH concentrations.

Sample	% NaOH	NaOH (g)	H_2O (g)
1	0	0	100
2	5	5	95
3	10	10	90
4	12	12	88
5	15	15	85

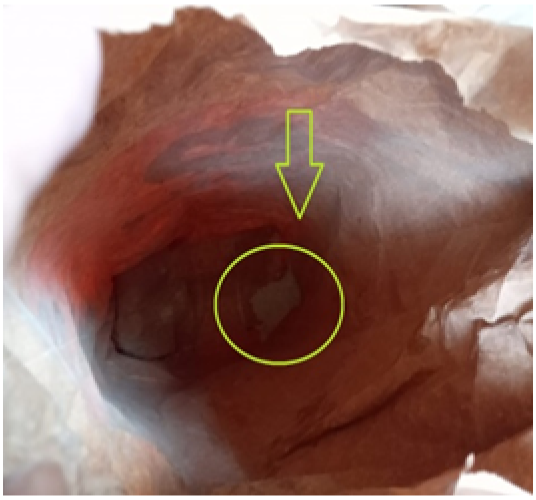

Figure 4. Packaging with cement residue at the bottom.

Figure 5. By-product obtained through grinding.

The mass of by-product obtained for each 25 Kg bag of cement and the respective absolute densities (mass divided by a 100 cm^3 container) were verified. Finally, the by-product was produced in sufficient quantity for granulometric analysis, with reference to the EN 933-1 standard - Tests of the geometric properties of aggregates Part 1: Granulometric analysis sieving method of 2014 [3].

Results and Discussion

Validation of the optimal concentration of NaOH

NaOH on samples contaminated with cement in the first 6 hours of drying were observed. At the end of the cycle, only the sample with 0% NaOH did not show a brittle structure Sample 3, with 10% NaOH content, showed brittleness before samples 4 and 5, which had a higher concentration of NaOH, which can be related to a possible variation in the concentration of cement residue impregnated in the sample (Table 2).

A concentration of 10% was established and monitoring of drying at 100°C after 6 hours, since it would be necessary to produce a larger volume for the next tests. The observed hydrogen ion potential (pH) of the valid solution was 13.62 (Table 3).

The 3 samples of kraft paper free of cement residues and subjected to a concentrated NaOH solution showed partial brittleness compared to the samples contaminated with cement (Table 4).

It was observed that the effect of Portland cement residues led to the setting of swollen pulps, which facilitated the processing of the by-product.

Checked quantities

The presence of cement residues in the folds at the bottom of the packaging is common. In the three verified samples, this loss was calculated at an average of almost 0.1% compared to the 25 Kg bag (Table 5). It was also observed that, despite the dehydrated packages, the by-product mass showed a small increase, which can be explained by the NaOH residues present in the samples (Tables 5 and 6).

The loss of Portland cement per bag can be considered high if compared to the amount of bagged cement produced in the world, especially those with folds at the bottom of the packages. This can be widely discussed between producers and consumers of bagged cement. If you consider the aforementioned SNIC data [4] it can be calculated that this loss would represent the equivalent of close to 32 million tons in 2020 in Brazil alone. However, the tests showed that the cement residue can contribute to the transformation of Kraft paper under the effect of NaOH into a by-product of low granulometry.

Table 2. Sample results according to NaOH content and time at 100°C.

Sample	NaOH concentration (%)	Time (hours)		
		6	12	24
1	0	N	N	N
2	5	N	N	B
3	10	B	B	B
4	12	N	B	B
5	15	N	B	B

Caption: B– Brittle N- Not Brittle

Table 3. Details of the validated solution.

Water (g)	NaOH (g)	NaOH (%)	NaOH (g/mol)	pH
90	10	10	2.5	13.62

Table 4. Result of samples without Portland cement residue, with 10% NaOH content and submitted to 100°C.

Sample	Time (hours)		
	6	12	24
1	N	N	N
2	N	N	B
3	N	N	B

Caption: B– Brittle N- Not Brittle

Evaluation of granulometry

As for the granulometry, evaluated according to the reference standard, observing a sampling of approximately 730 g, where the total of 457 g was retained in the meshes between 0.250 and 0.50 mm, which represents 62.60% of the sample.

Thus, the by-product of low granulometry was established (Figure 6). According to the data in Table 6, it can be calculated that approximately 6,000 bags, after being transformed into this by-product, would occupy a volume of 1 m^3, facilitating disposal. Some parts of the packaging were not affected by the process, being crushed and separated into fibres of varying sizes (Figure 7). New studies may improve the effectiveness of the process and/or observe their potential (Figures 6 and 7).

Conclusion

A possible technology for disposal of packages contaminated with Portland cement was demonstrated, which could be an option to minimize pollution for those discarded in large volumes, minimizing CO_2 emissions. The process is based on sodium hydroxide and also observes cement residues. There is a partially validated methodology regarding NaOH concentration, drying and grinding time. It is recommended that the packaging for this process be contaminated with Portland cement, taking advantage of those identified losses. The by-product of low granulometry and another by-product in the form of fibres were constituted, where both can offer benefits in other processes. In order to reduce consumption, the production of these by-products can be optimized, including sustainable disciplines, such as methods for reusing water and sodium hydroxide. Economic viability can also be calculated compared to current destinations. The next phase of the research is to detail the composition of the by-product and study it in the partial replacement of natural resources.

Table 5. Amount of Portland cement waste in verified packaging.

Samples	Cement Waste (g)	Loss (%) (for 25Kg bag)	Average Waste (g)	Average Loss (%)
1	15.0	0.06	-	-
2	26.4	0.11	20.64	0.08
3	20.5	0.08	-	-

Table 6. By-product mass and density results for each packaging sample.

Samples	Mass of Bags (g)	by-product Mass (g)	Density (g/cm^3)	By-product Average mass (g) /bag	Mean Density (g/cm^3)
1	66.7	69.0	0.46	-	-
2	65.7	76.9	0.49	75.17	0.45
3	68.1	79.6	0.41	-	-

Figure 6. By-product after multipack processes.

Figure 7. Crushed part that did not have the expected effect.

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