Giving Cigarettes a second life: the E-tijolo project

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ABSTRACT: Portugal presented 1,46 million smokers in 2014, resulting in about 2220 tonnes of cigarette butts per year. Such waste generates several harmful consequences to environment and public health. In this alignment, the current study purposes the incorporation of this waste in ceramic material to minimize its impacts. Cigarette butts were incorporated in clay fired bricks (0%, 2,5% and 5% (w/w)) and tested regarding their compressive strength, water absorption and density. The results achieved with the waste incorporation indicated as expected that the main properties are reduced by the incorporation of cigarette butts. Moreover, the reduction in dry density implies a decrease of the clay content showing also that this waste has an interesting potential in the production of clay fired bricks.

1 INTRODUCTION

Nowadays, the problematic of cigarette butts is increasingly evident. Cigarette butts waste is a huge pollutant, the problem begins with tobacco manufacturing and transporting. Researchers estimate the annual global environmental costs of tobacco manufacturing results in 2 million metric tonnes of solid waste, 300 000 metric tonnes of nicotine-contaminated waste and 200 000 metric tonnes of chemical waste (Lee, Botero, & Novotny, 2016). The Carnegie Mellon University's Green Design Institute performed an Economic Input-Output lifecycle assessment (EIO-LCA) concluding that USA's tobacco industry by its own is responsible for releasing 16 million metric tonnes of CO₂ (Proctor, 2012). Deforestation is the first negative consequence of the tobacco industry, being responsible for 4% of the worldwide deforestation (Lee et al., 2016).

In a worldwide perspective, in 2012, 6.25 trillion cigarettes have been consumed, releasing through the smoke denotative amounts of toxicants and pollutants directly into the environment. In a single year, the global tobacco smoke contributed with thousands of metric tonnes of carcinogens, other toxicants, and greenhouse gases. The toxic emissions include 3000–6000 metric tonnes of formaldehyde; 12000–47000 metric tonnes of nicotine; and the three major greenhouse gases found in tobacco smoke – carbon dioxide, methane, and nitrous oxides (DeBardeleben, 1981; Aeslina Abdul Kadir & Mohajerani, 2010).

The post-consumer waste cigarette butts also impact the environment. About two thirds of used cigarettes are being thrown away on the ground, resulting, each year, between 360 and 680 million kilograms of waste tobacco products in the world. Although the waste volume is frightful, the main harmful problem is the 7000 toxic chemicals contained in burnt cigarettes. Those toxic chemicals accumulate in the environment, ending up on the streets and contaminating fresh and marine water. Cigarette butts discharged contain dangerous chemicals including nicotine, arsenic, heavy metals (such as lead, copper, chromium, and cadmium) and PAHs, which can induce public health problems, such as cancer (Novotny & Slaughter, 2014; Wright, Rowe, Reid, Thomas, &

Figure 1: Possible pathways for human health risks due to the tobacco product wastes (Novotny & Slaughter 2014).

Galloway, 2015). The possible pathways for human health risks due to the tobacco product wastes are presented in Figure 1.

In terms of life cycle, nowadays, cigarette butts are the final waste of tobacco products. The cigarette butts are considered the major single type of litter by count (Novotny & Slaughter, 2014). They constitute about 30-40% of all items caught in urban and coastal clean-ups. Considering that in 20 cigarettes are present 3,4 g of filters, the estimated discarded from global cigarettes consumption was about 340-680 million kg in 2014, excluding the weight of tobacco scraps and other byproducts (Novotny & Slaughter, 2014; Witkowski, 2014).

Figure 2: Quantification of cigarettes smoked daily, in Portugal.

The discarded cigarette butt consists of unsmoked remnant tobacco, the paper wrap remnants, and the filter. The filters may aggravate the potential environmental effect of chemicals leached from butts, being essentially a nonbiodegradable plastic compilation of cellulose acetate fibers. The plastic particles and their toxicants may never disappear from water or soil and may continue leaching chemicals for up to 10 years, even if exposed to UV rays. Individually, each one presents a private environmental concern (Novotny & Slaughter, 2014).

In Portugal, 1,46 million smokers have been accounted for in 2014 (INE, 2014). Figure 2 **Erro! A origem da referência não foi encontrada.** shows the average of cigarettes smoked in Portugal, daily. From the inquired smokers, 45 % reported smoking up to 10 cigarettes per day, 46% smoke between 11 and 20 cigarettes, and 9% reported smoking a pack or more. Considering the best possible scenario (45% of Portuguese smokers consume 1 cigarette, 46% smoke 11 cigarettes and 9% smoke 21 cigarettes), it corresponds to approximately 10,8 millions of cigarettes *per day*. Moreover, as the calculated weight of 10 cigarette butts is 3.5 g, it translates to 3780 kg of cigarette butts being daily produced, meaning that in one year, approximately 1380 tonnes of cigarettes butts would be produced in Portugal.

On the other hand, considering the worst case scenario (45% Portuguese smokers consume 10 cigarettes, 46% smoke 20 cigarettes and 9% smoke 30 cigarettes), that would correspond to approximately 23.9 millions of cigarettes consumed *per day*, 8 380 kg of cigarettes butts being wasted daily and therefore, producing annually approximately 3059 tonnes of cigarettes butts in Portugal.

Accordingly to these premises, a middle ground can be considered. In this way, an average of 2220 tonnes of cigarette butts are produced, annually, in Portugal.

Nowadays, the main destination of cigarette butts corresponds to the landfill, and its disposal together with municipal solid wastes (World Health Organization, 2008, 2017). Considering the cigarette butts potential, this disposal is not environmentally and economically sustainable. The highest disadvantage is the fact that this waste remains as an environmental hazard, containing toxic substances and organic content which are becoming increasingly expensive and problematic (Aeslina Abdul Kadir & Mohajerani, 2010).

In 2010, a study of Aeslina Abdul Kadir and Abbas Mohajerani from University of Melbourne suggested an attractive alternative incorporating cigarette butts into building material composites, such as a brick. In this study it was observed that: (1) the density has been reduced up to 30%; (2) a reduction of compressive strength up to 90%; and (3) the absence of metals in leachate (Aeslina Abdul Kadir & Mohajerani, 2010). The main reason appointed for such a decrease in compressive strength is the cigarette butts sized that leads to clay fired bricks with many holes, and consequently with less resistance. Therefore and because it can be contaminated, it is important to consider its pre-treatment in order to stabilize and homogenize the waste for incorporation in ceramic materials.

The main goal of this study is to perform an initial evaluation of the influence of incorporating pre-treated cigarette butts in clay fired bricks and how it performs regarding water absorption, density and compressive strength.

2 MATERIALS AND METHODS

The study presents an experimental testing of cigarette butts incorporation in bricks, namely water absorption, density and compressive strength. The production of bricks with this incorporation needs a pretreatment for the raw materials preparation. The process is described in below. The second part is the process itself, being the mix of waste with the clay and the brick production. In the end, several complementary tests were performed to analyze the bricks. The raw materials used to produce clay fired bricks were, clay provided by local producer, water and cigarette butts collected in local shops and by *Laboratorio da Paisagem* from Guimarães municipal city hall.

2.1 Pretreatment

The pretreatment of the cigarette butts is fundamental for the correct mixture of raw materials, in order to have an homogeneous and non-contaminated raw material. Thus, the first step is the sterilization of cigarette butts in the autoclave. Posteriorly, the cigarette butts are dried in an oven at 100 °C during 2h and crushed in a mill with a 2 mm sieve.

Regarding the clay, it must be dried in an oven during 24h at 100 °C and passed in a roller mill.

2.2 Incorporation in bricks

For the incorporation in bricks, firstly clay and the waste should be mixed with water for a complete homogenization, during 15 min. Then the mold, whose dimensions are 22 x 11 x 7 cm (L x W x H), is filled with the mixture, which is subsequently pre-dried at 40 °C overnight. A final drying at 110 °C during 2h is required. The cooking of the fresh brick is performed at 1000°C in a muffle. In order to perform the testing, three different percentages of cigarette butt incorporation have been produced. Namely a prototype with i) 0% of waste incorporation into the brick (1) ii) 2.5% of waste incorporation into the brick (2) and iii) 5% of waste incorporation into the brick (3). **Erro! A origem da referência não foi encontrada.** details the brick production procedure with the approximate number of cigarette butts.

Table 1: Raw material used in bricks production

Sample	Clay mass (g)	Cigarette butts mass (g)	Cigarette butts number
1	2500	0	0
2	2438	63	175
3	2375	125	350

2.3 Complementary Assays

The experimental testing of the three prototypes included the: the mechanical resistance, the dry density and the water absorption. All tests have been carried out following the specific norms for clay masonry units and the results have been expressed using the mean of two values.

2.3.1. Mechanical Strength

For the mechanical strength, the compressive strength has been used as mechanical resistance indicator, according to EN 771-1. This test was performed using the Impact Test Equipment Building 21 Stevenston Ind. Est. Stevenston Ayrshire KA20 3LR C104 2005 version. The testing equipment is software-controlled with the testing specification and configuration data acquisition system. The specimen tested have been placed in the testing area, then increasing force in KiloNewton (kN) has been applied. The testing has been ended when the software has detected a loss of strength due to the breakage of the specimen. In order to improve accuracy of the results, the specimens, evaluated in duplicate, have been carefully aligned and placed at the testing area to ensure uniform loading over the total area of the brick.

The compressive strength of each specimen has been calculated by the **Erro! A origem da referência não foi encontrada.**:

$$C = Ka \times (1000P/A)$$

Where, C= Compressive strength (MPa); P= Total failure load (N); A= Area (mm²) and Ka= Determined

2.3.2. Dry Density

The dry density of the standard clay brick and the clay-cigarettes butts bricks have been measured according to EN 772-13. The samples have been manufactured with the standard dimensions of 210 x 110 x 70 mm, evidencing a mean value near to 0.5 mm. In order to measure the dry density, the specimens have been dried at 110±8 °C with intervals at least of 4h until constant weight has been observed. Consecutive weight has been taken as weight of the sample after cooling to room temperature. These tests were performed in duplicate.

2.3.3. Water Absorption

The water absorption test of the bricks has been done according to EN 772-11. In order to perform this test, the specimens have been prepared and dried in an oven at 105±5 °C until constant mass. Then, they the samples have been rested to cool to room temperature before their weighting.

Each unit was placed in the tank with water at room temperature. Firstly, the test has been done with 1/3 of the volume of the brick immersed in water. Then, the brick has been immersed until 2/3 of its volume. Finally, the specimens have been submerged for 24h. Before weighing the bricks, all the excess water has been removed from all brick surfaces. To calculate the water absorption, the **Erro! A origem da referência não foi encontrada.** has been used as follows:

$$w_m = (m_w - m_d)/m_d \times 100$$

Where, w_m is water absorption (%); m_w is wet mass (g) and m_d is dry mass (g).

3 RESULTS AND DISCUSSION

Table 2 lists the main results of the tests described before. According the compression strength, the incorporation of milled cigarette butts influences negatively this property being reduced in the range between 52% to 23%, respectively for incorporations of 2.5% and 5%. This decrease is in accordance with the literature (Aeslina Abdul Kadir & Mohajerani, 2010). However, the compression strength values are bellow the reported by Abdul Kadir study (2010) (Aeslina Abdul Kadir & Mohajerani, 2010). This is explained by the differences in the raw material used and the procedure test, namely the compression velocity. Nevertheless, the results are comparable among samples and the main trend is similar to the minimum reported values for clay fired bricks in the standard NBR 7170 (ABNT-Associação Brasileira de Normas Técnicas, 1983).

Table 2: Complementary assays

Sample	Incorporation rate (%)	Compression strength (MPa) $\pm$ STDV	Dry density (Kg/m³)	Water absorption (%)
1	0	4.47 $\pm$ 0.704	1545.55 $\pm$ 12.11	19.91
2	2.5	2.31 $\pm$ 0.035	1412.04 $\pm$ 10.98	24.26
3	5	1.05 $\pm$ 0.35	1340.11 $\pm$ 5.70	27.85

Relatively to the dry density, all samples are considered as High Density units, according to EN 771-1 (Eurocode, 2003). For instance, the sample 1 presented a value of 1545.55 kg/m³. This result was the highest of the tested bricks, demonstrating that, as expected, the cigarette butts incorporation reduce the dry density. The sample 3 exhibited less 13 % regarding e sample 1. Also, sample 2 shows a reduction of the dry density less evident but still about 9%. Comparing to the Kadir's study (2010), the standard brick presents a dry density of 2118 Kg/m³. The 2.5% and 5 % of incorporation presents a density of 1941 kg/m³ and 1611 kg/m³, respectively (Aeslina Abdul Kadir & Mohajerani, 2010). These changes can be justified by the different raw material, cooking times and also by the incorporation of crushed cigarette butts, different to Kadir's study in which the cigarette butts have been incorporated in the whole way.

Furthermore, observing the water absorption test results it is possible to claim that the bricks are capable to absorb water. For instance, sample 1 presented 19.91% of water absorption, corresponding to the minimum absorption percentage. The water absorption increased with increasing waste incorporation. The most probable explanation lies in the porosity increase due to cigarette butts incorporation and volatilization during the cooking process.

4 CONCLUSIONS AND RECOMENDATIONS

The incorporation of cigarette butts in bricks is a potential solution for the environmental issue and health concerns. Thus, the consequences of this waste presence in the environment can be minimized. As shown by the results of the performed testing, the cigarette butts incorporation in bricks reduce the main properties (compressive strength, density and water absorption) of the clay fired brick. This may pose problems in the construction of higher structural walls but not in interior walls. Nevertheless, more studies are being made in order to obtain the ideal amount of milled cigarette butts that can be incorporated without causing a high decrease of mechanical properties.

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