Reception: **May 27, 2021** | Acceptance: **August 12, 2021** | Publication: **June 1, 2022**

Concrete mixed with cigarette butts as a proposal to minimize their waste in the environment

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To quote this article:

Hernández Pacheco, K. S. ., Arroyo Matus, R. ., & Sánchez Tizapa, S. (2022). Concreto adicionado con colillas de cigarrillo como propuesta para la minimización de estos residuos en el medio ambiente. *Espacio I+D, Innovación más Desarrollo, 11*(30). https://doi.org/10.31644/IMASD.30.2022.a05

— Abstract—

Cigarette butts take from two to ten years to degrade; they have substances harmful to the environment because a single cigarette butt can contaminate eight liters of seawater and up to 50 liters of drinking water. They are not biodegradable waste so throwing them away along with organic waste is not an alternative. It is a tiny waste difficult to recycle; for these reasons, innovative alternatives must be sought for their disposal and final destination.

In the construction industry, concrete is one of the most used materials in the world due to its physical and mechanical characteristics before various demands and its vast local availability. The objective of this work is to use cigarette butts in concrete as an alternative for their waste disposal, thus reducing the percentage of waste in the environment.

Mixtures with compressive strengths of 24.5 and 29 MPa were designed to which the cigarette butt was added in different percentages. Concrete tests were performed in a hardened state of cylindrical compression and indirect traction. In the cool state, the workability of the concrete, temperature, density, and air content were measured; favorable results were obtained, demonstrating that the addition of cigarette butts to concrete as an alternative for the final disposal of such waste is viable.

Keywords:

Concrete; Butts; Cigarette.

Environmental pollution has been increasing in recent years, which is why there was a need to educate society on proper management, control, and recycling of waste; through great efforts on the part of governments, institutions, and private enterprises. Today, there is a gradual awareness of responsible waste management (Lizano, 2010).

Within the long list of waste, there is paper, plastic, and even technological waste, but in this list, little has been done for cigarette filters. For many, it is a small role that does not need to be discarded or treated, but the reality is different, and there is no awareness of it.

Currently, according to numerous studies, it has been determined that cigarette butts are considered the most common solid waste worldwide. There are indications that in the world there are 6 million smokers who consume an average of three cigarettes a day generating a total of 18 million cigarettes per day (Cai and others, 2019). It is estimated that 767 million kilograms of cigarette butts are discarded each year (Novotny, 2009). In another study made in 2011 by Ocean Conservancy, it was determined that a single cigarette butt can contaminate eight liters of seawater and up to 50 liters of drinking water. Throwing them away along with organic waste is not an alternative because they pollute them and do not degrade, thus nullifying the possibility of transforming them into compost; the same happens when they are mixed with recyclable waste because they prevent them from being used. They are a waste difficult to recycle due to the number of materials that compose them; therefore, innovative, and non-polluting alternatives have to be sought for their disposal and final destination.

The general objective of the research is to evaluate the technical feasibility of adding cigarette butts in the elaboration of concrete, to minimize the high environmental impact that they generate to guarantee that all their contaminants and toxic agents are "encapsulated" in concrete.

It is intended that concrete mixed with cigarette butts can be used without losing its original resistant characteristics, but that the materials that make up the cigarette butts add other characteristics such as lightness, thermal insulation, and, above all, it is a viable alternative for the final disposal of this type of waste. It is also sustainable, feasible to be introduced and transformed into a common practice in the reinforced concrete elaboration process.

BACKGROUND

A cigarette butt can take anywhere from 18 months to 10 years to decompose (they are not biodegradable). Many smokers have a bad habit of throwing cigarette butts on the floor when they finish smoking. The rains usually drag this waste to the water sources, where they give off their chemicals, which contain toxic contaminants such as tar, benzene, ammonia, and cadmium, among others (UNE, 2015); which can contaminate up to 50 liters of water. There are also mercury, lead, arsenic, uranium, torino and cadmium, which together are substances that can infiltrate soil and groundwater (Novotny, 2009). It is considered that more than fifty percent of the forest fires on the planet are caused by lit cigarette butts (Novotny, 2009).

Cigarette filter composition: cigarette filters are designed to absorb the accumulation of vapors and smoke particles, to retain tar and other harmful products, both those carried by tobacco and those produced in the combustion of the cigarette, before they reach the lungs of smokers (Guevara Lizano, 2010).

Filters, in general, have the following components:

- A cellulose acetate filter "plug": 95% of cigarette filters are made of cellulose acetate (plastic), and the rest are made from paper and rayon.
- Cellulose acetate is a relatively hard, shiny, colorless, transparent, and amorphous thermoplastic material with good clarity, UV stability, and moderate chemical resistance; in Figure 1, you can see a graph of a conventional cigarette (Lincango & Mancero, 2020)

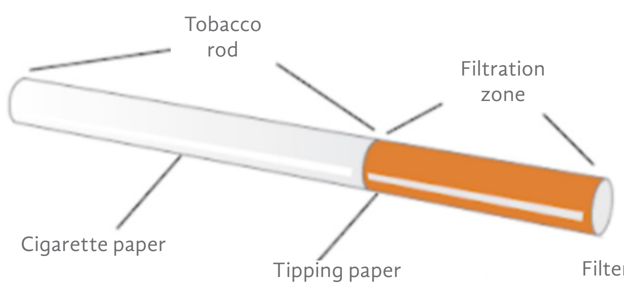

Figure 1. Parts of a conventional cigarette. Source: Lincango, J., & Mancero, E. (2020)

Cigarette wrapping and butt: The paper used to wrap tobacco is made from flax fiber. Manufacturers add various chemicals to the paper, including salts to speed up or control the rate of combustion. The rate of combustion has an important effect on the number of inhalations that can be obtained by the smoker, the smoke, and the performance.

Use of cigarette butts in building materials: As mentioned above, cigarette butts are harmful waste to both health and the environment. There are various initiatives to mitigate the environmental impact they cause. Dealing with cigarette residues is one of the world's most difficult environmental dilemmas due to the high content of toxic resources they contain, metals such as arsenic, chromium, nickel, and cadmium (Cortez Camacho & Ponce Muñoz, 2019).

According to (Mohajerani, 2016) "one man's garbage is another man's building material", so the idea was to turn cigarette butts into raw material to produce ecological bricks. In this regard, Mohajerani points out that: "Incorporating cigarette butts into bricks can effectively solve a global garbage problem. Recycled cigarette butts can be placed on bricks, without fear of leaching or contamination. They are also cheaper to produce, in terms of energy needs since the energy cost decreases as more cigarette butts are introduced into production." We can see in Figure 2 that the physical appearance of these bricks with cigarette butts is very similar to that of normal bricks.

Figure 2. Bricks made from cigarette butts. Source: http://www.archdaily.co/co/791421/investigadores-de-rmit

Concrete: Concrete is a building material composed of large particles formed by a continuous cementitious matrix that binds to an aggregate of fine particles (aggregate or fine aggregate or sand, and aggregate or coarse aggregate) (Sánchez de Guzman, 1993).

Materials made from mortars and Portland cement concrete are attractive to use as a building material; because they offer a good cost/benefit ratio, are durable, and have strength and rigidity suitable for structural uses. Additionally, in a fresh state, they are easily moldable, so they can adopt shapes as capricious and complex as you want (Lopez Roman & Mendoza Escobedo, 2016).

Incorporating fibers into a concrete blend is efficient in improving the mechanical performance and durability of hardened Portland cement concrete, by reducing and controlling the spread of microcracks generated by retraction and allowing the redistribution of internal stresses that tend to crack the cementitious matrix (Robayo, Mattey, & Delvasto, 2013).

METHODOLOGY

A cigarette butt collection campaign was carried out with the support of the Universidad Autónoma de Guerrero through the department of UAGro Verde in restaurants, bars, schools, and parks in the cities of Chilpancingo and Acapulco, Guerrero, Mexico. The experimentation process was carried out in the soil and materials laboratories of the School of Engineering of the UAGro.

Several aspects were analyzed: The workability or manageability of the concrete mixture using the water-cement ratio (W/C), the compressive strength acquired on days 7, 14, and 28 days of normal concrete and concrete with the same characteristics as the normal one was compared but added with cigarette butts. The flexural strength of the concrete was also evaluated at 28 days, observing in all cases the stress to rupture, the types of failures of the samples under study, and the different eventualities.

To achieve the objectives of the experimental development, two designs of 28-days compressive strength mixtures were carried out, 24.5 MPa (250 kg/cm^2) and 29.4 MPa (300 kg/cm^2). Once the designs of the mixtures were obtained, 0.5%, 1%, and 2% of cigarette butts were added, and a control mixture without the addition of cigarette butts was also made.

The compressive strength of concrete was obtained from cylindrical specimens made, cured, and tested per ASTM C31 (ASTM C31 / C31M-21a, 2021), ASTM C192 (ASTM C192 / C192M-19, 2019), and ASTM C39 (ASTM C39 / C39M-21, 2021) standards, respectively, to obtain the control mixtures that would be used throughout the experimental work.

The experimental work consisted of several stages; in the first instance, we took into account the physical properties of materials to determine parameters for mixture designs.

PROCESSING OF CIGARETTE BUTTS

Collection of cigarette butts. A survey was conducted to determine the most frequent smoking sites in the city of Chilpancingo, Guerrero; with the help of the Department of Ecology of the Universidad Autónoma de Guerrero (UAGro) and following an adequate biosecurity protocol, plastic containers were distributed in various bars and restaurants in the city. An awareness and collection campaign was also carried out on the university's social networks (Facebook and Instagram) to collect cigarette butts individually from smokers.

Cleaning of cigarette butts. The paper and adhesive were removed from the cigarette butts; then, the cigarette butts that were complete were selected and those that were very dirty or burned were eliminated. Figure 3 shows the state in which the cigarette butts were obtained.

Figure 3. Different cigarette butts with a wrapper. Source: Image taken in the laboratory

Shredded cigarette butts. Cigarette butts were shredded into thinner strands of, approximately, 0.5 to 1 mm thick. From each shredded butt, an average of 16 portions of the mentioned diameter was obtained. Thinner strands like those on the left side of Figure 4 were not considered a viable option for this project.

Figure 4. Strands obtained after shredding the butts. Source: Image taken in the laboratory

Characterization of cigarette butts. For the characterization of the cigarette butts, the following parameters were considered:

a) Length and weight: Different butts were measured and weighed at random, from which an average length and weight were obtained (Table 1).

Table 1
Physical characteristics of cigarette butts

Average Measure of Cigarette Butts	
Complete	**Shredded**
25.6 mm	20.7 mm
Cigarette Butts Width	
8.51 mm	
Average Wight of Cigarette Butts	
0.178g	

Source: Own elaboration

b) Absorption and density: To determine the absorption and density of the cigarette butts, since there is no standardized procedure, the tests carried out in soil mechanics were adapted to determine these parameters (Figures 5 and 6).

Figure 5. Absorption and density tests in cigarette butts. Source: Image taken in the laboratory

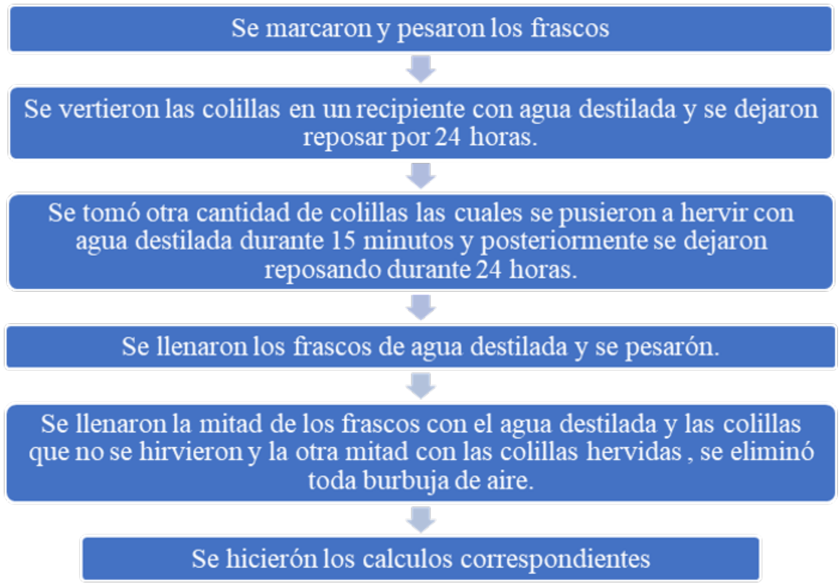

Figure 6. Procedure to obtain the absorption and density of cigarette butts. Source: Own elaboration

Design and elaboration of mixtures. Concrete mixtures were made with an f'c at 28 days of 29.4 and 24.5 MPa (250 kg/cm^2 and 300 kg/cm^2) to compare the mechanical properties of normal concrete with concrete mixed with cigarette butts in percentages of 0.5%, 1%, and 2% (Tables 2 and 3). Several aspects were analyzed: The workability or manageability of the concrete mixture using the water-cement ratio (W/C); the compressive strength acquired in 7, 14, and 28 days; and the concrete flexural strength at 28 days. We observed the stress to rupture in all cases, the types of failures of the samples under study, and the different eventualities.

Table 2
Mixing design for f´c = 24.5 MPa (250 kg/cm²) and 29.4 MPa (300 kg/cm²) by the ACI method

Resistance	29.4 MPa (300 kg/cm2)		24,5 MPa (250 kg/cm2)	
REV=10				
Material	1 M^3	0.01445 M^3	1 M^3	0.01445 M^3
Cement	260	3.757344814	330	4.768937648
Gravel	950	13.7287599	980	14.16229968
Sand	925	13.36747674	810	11.70557423
Water	200	2.890265241	205	2.962521872
Cigarette Butts				
0.5%	11.675	0.168719233	11.625	0.167996667
1%	23.35	0.337438467	23.25	0.335993334
2%	46.7	0.674876934	46.5	0.671986669

Source: Own elaboration

During the mixing process, some parameters were determined for concrete in the fresh state, per ASTM standards, such as slump, unit mass, and air content by the pressure measurement (See Figure 10).

Figure 7. Density test and concrete slump. Source: Image taken in the laboratory

The compressive strength of concrete, was obtained from cylindrical specimens made, cured and tested at different ages, in accordance with standards ASTM C31 (ASTM C31 / C31M-21a, 2021), ASTM C192 (ASTM C192 / C192M-19, 2019) and ASTM C39 (ASTM C39 / C39M-21, 2021) (Figure 8).

Figure 8. Cylinders with compressive strength of 24.5 MPa (250 kg/cm^2).
Source: Image taken in the laboratory

For each mixture design, twelve cylindrical specimens of 10 x 20 cm were tested at compression at 7, 14 and 28 days (ASTM C39 / C39M-21, 2021); at flexural, three cylindrical specimens of 15 x 30 cm were tested at 28 days (ASTM C496 / C496M - 17, 2017).

RESULTS AND DISCUSSION

To determine whether the concrete mixed with cigarette butts proposed in this work reaches the mechanical conditions to be used in practice, several tests were performed to determine the optimal quantities in each specified design. A design of added mixtures with percentages of 0.5%, 1%, and 2% of cigarette butts and a control mixture for each compressive strength proposed, and the properties in the fresh state of all the elaborated mixtures were evaluated; below are the results obtained in the applied trials (Table 3).

Table 3
Test results for fresh concrete

f´$_c$ = 24.5 MPa (250 kg/cm^2)				
Characteristics / Mixture	Shrinkage (10 ± 2)	Air %	Unit mass kg/m^3	Temperature
f´$_c$ = 29.4 MPa 0.5%	9	2.8	2789.21	29 °C
f´$_c$ = 29.4 MPa 1%	8	3	2576.47	27 °C
f´$_c$ = 29.4 MPa 2%	7	2.9	2657.65	28 °C
f´$_c$ = 29.4 MPa control	9.5	2.6	2697.96	34 °C
f´$_c$ = 29.4 MPa (300 kg/cm^2)				
f´$_c$ = 24.5 MPa 0.5%	8	2.9	2700.21	28 °C
f´$_c$ = 24.5 MPa 1%	7.5	3.1	2467.37	26 °C
f´$_c$ = 24.5 MPa 2%	7	3	2595.59	28 °C
f´$_c$ = 24.5 MPa control	11	2.7	2689.96	33 °C

Source: Own elaboration

Compressive strength. The compressive strength is the most important characteristic to evaluate in concrete. It is one of the parameters that will determine if it is viable to use the cigarette butts in the concrete without affecting its resistance; thus, cylindrical specimens of concrete in a hardened state were tested at 7, 14, and 28 days (table 4 and figures 9 and 10).

Table 4
Compression test results

Compressive test results				
f´$_c$ = 24,5 MPa (250 kg/cm^2)				
	Control mixture	M1= 0.5%	M2 = 1 %	M3= 2%
Days	0	0	0	0
7	14.04	14.99	15.52	14.65
14	22.26	19.95	19.01	21.57
28	24.03	20.78	19.00	20.01
f´$_c$ = 29.4 MPa (300 kg/cm^2)				
7	12.30	19.19	19.26	19.91
14	25.67	22.23	22.29	22.96
28	29.39	18.03	18.84	18.81

Source: Own elaboration

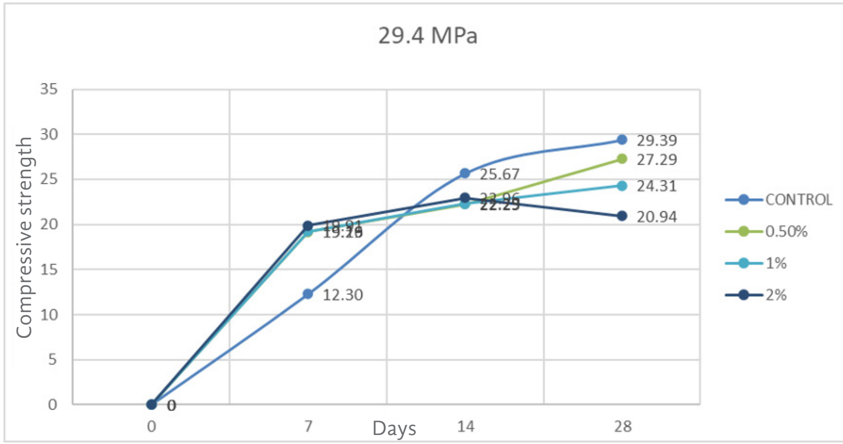

Figure 9. Comparative graph of the compression results for the design f´c = 29.4 MPa with different percentages of cigarette butts. Source: Own elaboration

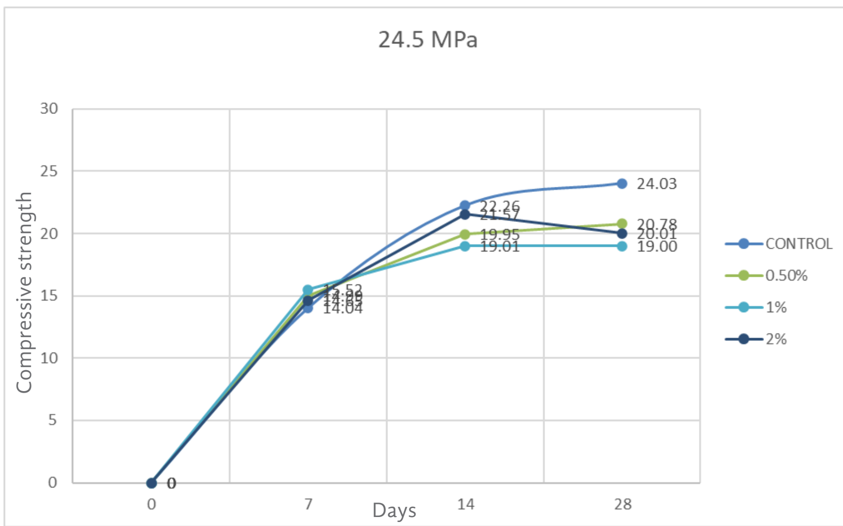

Figure 10. Comparative graph of the compression results for the design f´c = 24.5 MPa with different percentages of cigarette butts. Source: Own elaboration

The experimental results of the tested specimens show that the mixture with the addition of 2% of cigarette butts had an increase in its resistance up to 14 days and decreased considerably at 28 days, this is because the presence of butts in the concrete inhibited the hydration heat process in the concrete since at the time of testing these cylinders we observed there was humidity inside.

With the comparison of the results obtained in the different mixtures for the strength of the concrete, the best results were obtained with the 5% cigarette butt mixtures.

Photographs of the experimental process are shown in Figure 11. On the left, the cone is shown in the press after completion of the compression loading of the specimen. On the right, the photograph shows the appearance of a fractured cylinder sample where the structure of the concrete containing the filaments of the material that constitutes the cigarette butts is observed.

Figure 11. Cylinder subjected to compression. Source: Image taken in the laboratory

Indirect tensile strength. Also known as the Brazilian test, is a test used to determine the tensile strength of concrete, which consists of applying an external compressive load on one side of the sample, while the opposite end to the load remains supported. In this way, two diametrically opposite forces are generated that produce a uniform distribution of transverse tractions along the load axis, causing the tensile rupture of the sample (ASTM C31 / C31M-21a, 2021). The results are shown in Table 5.

Table 5

Stress test results

Resistance to indirect traction		
Stress MPa test results		
Mixture	Resistance to stress MPa	Percentage concerning compressive
29.4 MPa 0.5%	2.63	8.93
29.4 MPa 1%	2.69	9.16
29.4 MPa 2%	2.61	8.89
29.4 MPa	2.75	8.88
24.5 MPa 0.5%	2.75	11.23
24.5 MPa 1%	2.72	11.12
24.5 MPa 2%	2.71	11.06
24.5 MPa	2.72	11.11

Source: Table obtained from the results of the stress tests of the concrete

A photograph of the stress test process of the specimen is shown in Figure 12. The failure is shown practically horizontal, which exhibits adequate experimental behavior without local faults due to cylinder heterogeneities. The foregoing shows that there is no interference of the cigarette butts material added to the concrete, creating a final product viable for the construction sector.

Figure 12. Tensile test failure. Source: Image taken in the laboratory

CONCLUSIONS

The fresh state characteristics of the concrete mixed with cigarette butts are very similar to those of concrete under normal conditions; a slight decrease in temperature is observed, which generates a longer setting time and, in turn, a more manageable mixture (Claros, 2020).

The incorporation of cigarette butts in percentages of 2% decreases the compressive strength after 14 days, the highest compressive strength was obtained with the concrete mixed with 0.5% of butts, in all mixtures a small increase in compressive strength was observed at early ages.

It should be noted that the incorporation of cigarette butts into the concrete does not alter the tensile strength, since the percentages are within the normal parameters.

The fresh and hardened characteristics of the concrete added with butts indicate the possibility of being used in non-structural concrete and open up a new alternative for other fields of application of this material in the construction sector.

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