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Analysis of sustainable concrete made from cigarette butts on bending strength

Análisis del concreto sustentable elaborado con colillas de cigarro en la resistencia a la flexion

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Abstract

In the research in the methodological aspect, the concrete mixture was designed, based on the ACI 211.1 standard; Cigarette butt fibers were included in the material with which the concrete was made to reuse materials that are polluting, and in this way a sustainable concrete was made. For the analysis and results, a press was used to test the compression pieces established by the NMX-C-083-ONNCCE-2014 Standard for concrete specimens. In the laboratory, the bending test was carried out with the NMX-C-191-ONNCCE-2015 in nine concrete beams, in a concrete sample the fibers of cigarette butt were added, in another polypropylene fibers were used, and a third sample of concrete without any fibers. The research concludes that the reuse of cigarette butt fibers to make hydraulic concrete will help reduce environmental pollution. The results of the compression tests were satisfactory for a concrete with f'c = 350 kg / cm^2. Bending test tests on concrete beams met MR = 45 kg / cm^2. Both design resistors.

Concrete, Sustainable, Flexion

Resumen

En la investigación en el aspecto metodológico se diseñó la mezcla de concreto, con base en la normativa ACI 211.1; se incluyó en el material con el que se fabricó el concreto, fibras de colillas de cigarro para reutilizar materiales que son contaminantes, y de esta manera se hizo un concreto sustentable. Para los análisis y resultados, se utilizó una prensa para ensayar las piezas a compresión que establece la Norma NMX-C-083-ONNCCE-2014 para especímenes de concreto. En el laboratorio se realizó la prueba de flexión con la NMX-C-191-ONNCCE-2015 en nueve vigas de concreto, en una muestra de concreto se le adiciono las fibras de colilla de cigarro, en otra se utilizó fibras de polipropileno, y una tercera muestra de concreto sin ninguna fibra. En la investigación se concluye que la reutilización de las fibras de colilla de cigarro para fabricar el concreto hidráulico, ayudara a disminuir la contaminación del medio ambiente. Los resultados de los ensayos a la compresión fueron satisfactorios para un concreto con f´c=350 kg/cm^2. Las pruebas de ensaye a la flexión en las vigas de concreto cumplieron con el MR=45 kg/cm^2. Ambas resistencias de diseño.

Concreto, Sustentable, Flexión

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Introduction

Normally, rigid hydraulic concrete pavements are manufactured with cement, stone aggregates such as sand and gravel, water and sometimes additives and / or additives. The pavements, unlike other structural elements such as columns, beams and slabs, are tested for bending, the Modulus of Rupture (MR) measured in kg / cm2 being important for this.
In this research, the fibers contained in the cigarette butts will be included in the mixture, to make a sustainable concrete, and in this way reuse that highly polluting material, thus contributing to the care of the environment, this because when it is consumed A cigarette the residue that remains is the cigarette butt or filter, which often reach the ground, and that with the rains no longer remains in the place where they were thrown, causing it to be transported to the drains as if it were rain residue, taking several years to degrade.

Butts contain substances that are harmful to the environment, such as nicotine, tar, hydrocarbons and cellulose acetate, as well as some heavy metals such as lead, cyanide and arsenic. So, instead of the cigarette butts being found contaminating the streets in cities, rivers or seas, they will be occupied for construction purposes on rigid pavements.

The different types of pollution in the environment by cigarette butts are described, both on the ground and in the water. Starting the research with the collection of the cigarette butts, to later obtain the fibers, laboratory tests were carried out on the stone aggregates to characterize them and with the results design the concrete mixture, the next step consisted of preparing three mixtures of concrete, one incorporating the fibers of the butts, another with polypropylene fibers, and a last without any fiber, testing specimens for compression and bending, to compare results and verify that the design f'c and MR were met.

1. Pollution to the environment by cigarette butt

1.1. Pollution to the environment

According to National Geographic (2018, para. 5):

Cigarette butts represent between 30 and 40% of the waste collected in urban and coastal cleaning activities. According to the Ocean Conservancy organization, throwing out a cigarette butt can contaminate up to 50 liters of drinking water, since the filter retains most of the nicotine and tar from the cigarette.

With the above it is clear that cigarette consumption not only affects the health of the person who uses it, it also negatively impacts the environment.

In addition, trees are cut down for the manufacture of cigars, for their paper and packs.

1.2. Soil contamination

“A recent study found that cigarette butts inhibit plant growth. Furthermore, they usually reach the waterways and eventually the oceans ”(National Geographic, 2019, para. 4). So you can be in a position to measure the enormous problem caused by cigarette butts on the ground, since it prevents the reforestation that planet earth needs so much.

National Geographic (2019, para. 1) also indicates that “smokers around the world buy around 6.5 billion cigarettes a year. That's 18 billion a day ”, of those billions of cigarettes, a huge amount of cigarette butts end up on the ground.

1.3. Water contamination

Taking into consideration the aforementioned, the contamination that a cigarette butt can cause in the water is worthy of reference, for the University of Costa Rica (2015, para. 5) and the: Ocean Conservancy Organization in 2011, a single cigarette butt contaminates eight liters of seawater and up to 50 liters of drinking water. This is because most filters are made of cellulose acetate, a polymer that can take up to 25 years to degrade.

In addition, if they reach the oceans, the substances that are released from the cigarette butts are very toxic to microorganisms. Finally, according to the University of Costa Rica (2015, para. 9) “cigarette butts are the number one object in waste collection, surpassing plastic bags and bottles”, hence the importance of reusing cigarette butts in concrete , to build rigid pavements.

Methodology

Collection and obtaining of fibers from cigarette butts

The material to be used for this research was cigarette butts, and although unfortunately it is a common waste, it does not mean that its collection is easy, since smokers do not have the culture of depositing them in the containers used for this waste. First, they resorted to establishments where these wastes could be found, such as shopping centers, family centers, and at the Universidad Veracruzana itself. In the aforementioned establishments, they requested to put small cans where people could be depositing the butt when they finished smoking the cigar, the collection by this means was little, because many people do not have a civic culture and they throw them directly on the ground. At the Universidad Veracruzana there are ashtrays in which a greater quantity was collected in less time, and the other great contribution of cigarette butts was through the same university students, who collected them themselves and elsewhere.

What was in the ashtray was separated because other garbage was also found, and later it was taken to the laboratory. The paper that covered the filter was removed, as well as the capsules that come inside and that are the ones that provide different flavors to the cigar. Once the fibers were clean, they were separated.

When cleaning the fibers, gloves and face masks were used as protection against the chemicals and substances found in them.

Figure 1 Obtaining and separating the fibers from cigarette butts
Source: Own elaboration (2021)

Tests performed on stone aggregates

The following tests were carried out on the samples of stone aggregates selected to make the concrete mixtures.:

- Reduction of aggregate samples (cracking), with the NMX-C-170-ONNCCE-1997 standard.
- Granulometric analysis, with the NMX-C-077-1997-ONNCCE standard.
- Loose and dry compacted dry volumetric mass, standard NMX-C-073-ONNCCE-2004.
- Water content by drying, standard NMX-C-166-ONNCCE-2006.
- Density and absorption of coarse aggregate, standard NMX-C-164-ONNCCE-2014.
- Fine aggregate density and absorption, standard NMX-C-165-ONNCCE-2014.

Concrete Mix Design

With the characteristics obtained from the gravel: with a maximum size of the coarse aggregate (TMA) of 20 mm, volumetric weight of 1325 kg / m3, a specific weight of 2.4, humidity of 6.6% and absorption of 4.9%; and sand: with a Modulus of Fineness (MF) of 2.8, a specific weight of 2.6, humidity of 14.7% and absorption of 1.5%, through the tests listed above, the hydraulic concrete mixture was designed with the ACI method. 211.1, also considering the following specifications:

The design resistance f'c = 350 kg / cm2 at 28 days of age, was specified so that the Modulus of Rupture (MR) of the pavement is 45 kg / cm2, which is already indicated for a pavement of medium traffic , with a slump of 14 cm and without including air, the cement used is CPC 40 RS with a specific gravity of 3.12. Adjusting for moisture and absorption, the actual proportion for a cubic meter of concrete, and for the volume required for the investigation, is presented in the following table:

Material	Actual ratio 1m3 (kg)	Required ratio (kg)
Cement (CPC 40 RS)	380	28.5
Sand	787	59.0
Gravel (TMA 20 mm)	848	63.6
Water	196 L	14.7 L

Table 1 *Concrete Mix Design*
Source: Own elaboration (2021)

For concrete added with polypropylene fiber, FIBRAMIX MICRO FIBRA 400 was used, and it recommends that a 400 gr biodegradable bag be added for each m3 of concrete. For the research, only 75 liters of concrete were made for each mixture, so, for the required proportion, a weight of 30 g of polypropylene fibers is needed, in the same way the same weight was used for the fibers of cigarette butts.

Testing of fresh concrete

First, the concrete mixture was made with the use of a mixer, the coarse aggregate (gravel) and a part of the mixing water were poured into it, the mixer was turned a few revolutions and the sand was added. Later, the cement is added, mixing is continued and the missing water is incorporated little by little. To have control of the mixing time, the timer is started once all the water in the mixture has been added. Cigarette butt fibers and polypropylene fibers are incorporated into the blends, after all other materials mentioned have been added.

The concrete is mixed for 3 minutes after having loaded all the materials into the mixer, and then it is allowed to rest for 3 minutes. The mixing is finished with another mixing period of 2 minutes, to finally obtain the fresh concrete sample, and again it is remixed. The following tests were carried out on the concrete mixtures in a fresh state:

- Obtaining the water content in the aggregates, standard NMX-C-166-ONNCCE-2006
- Temperature, standard NMX-C-435-ONNCCE-2010
- Revenue, standard NMX-C-156-ONNCCE-2010
- Unit mass, standard NMX-C-162-ONNCCE-2014

Making and curing of concrete cylinders and beams (specimens)

The concrete specimens were made in steel molds, with the characteristics indicated in (NMX-C-159-ONNCCE-2004, 2004) "The molds and accessories to make the concrete specimens must be made of steel, cast iron, or any other non-absorbent and non-reactive material with portland cement or other hydraulic cements"(p. 6).

The molds for the cylinders are 15 cm in diameter and 30 cm long, and those for the beams have a section of 15x15 cm and a length of 50 cm.

Figure 2 Concrete cylinder molds
Source: Own Elaboration (2021)

Figure 3 Concrete Beam Molds
Source: Own elaboration (2021)

The hydraulic concrete mixture was poured into the molds (cylinders and beams) based on the procedures indicated in the NMX-C-159-ONNCCE-2004 standard.

After 24 hours, the specimens were removed from the molds, to cure them in a humid environment and at a temperature of 23 ° C ± 2 ° C, according to the NMX-C-148-ONNCCE standard.

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The beams made to check the flexural strength, must comply with the above and additionally must be stored for a minimum period of 20 hours immediately before the test, in water saturated with hydrated lime. In addition to the fact that its surface should not be allowed to dry when executing the test, because it would induce tensile stresses in the fibers, which reduce the resistance to bending of the beam.

Results

After the concrete cylinders were cured, they were capped with sulfur and tested in the press shown in the following Figure:

Figure 4 Cylinder test to obtain the f´c
Source: Own elaboration (2021)

Of the concrete cylinders without any fiber, they were subjected to compression in the press, obtaining the following results.

Age Specimen (days)	P (kg)	A (cm^2)	Resistance f´c (kg/cm^2)
3	51550	176.715	291.71
7	60120	176.715	340.21
28	72260	176.715	408.91
Witness 28	73340	176.715	415.02

Table 2 Strengths of the 4 concrete cylinders without fibers
Source: Own Elaboration (2021)

The concrete cylinders with polypropylene fibers were subjected to compression in the press, obtaining the following results.

Age Specimen (days)	P (kg)	A (cm^2)	Resistance f´c (kg/cm^2)
3	51330	176.715	290.47
7	58870	176.715	333.14
28	70470	176.715	398.78
Witness 28	70630	176.715	399.68

Table 3 Strengths of the 4 concrete cylinders with polypropylene fibers
Source: Own Elaboration (2021)

The concrete cylinders with cigarette butt fibers were subjected to compression in the press, obtaining the following results.

Age Specimen (days)	P (kg)	A (cm^2)	Resistance f´c (kg/cm^2)
3	51130	176.715	289.34
7	57750	176.715	326.80
28	67280	176.715	380.73
Testigo 28	72370	176.715	409.53

Table 4 Resistances of the 4 concrete cylinders with cigarette butt fibers
Source: Own Elaboration (2021)

The resistance f'c of each cylinder is calculated with the following equation

$$f'c = P/A \quad (1)$$

Where:

f'c is the concrete compressive strength in kg/cm^2
P is the load at which the specimen fails in kg
A is the area of the section that receives the load in cm^2

As with cylinders, concrete beams are flexural tested after curing to obtain the Modulus of Rupture (MR), as it is an indirect procedure to determine the tensile strength of concrete, and is used in pavements, the test consists of applying the loads in the middle third of the beam span.

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Figure 5 Testing of beams to obtain the MR.
Source: Own Elaboration (2021)

The concrete beams without any fiber were tested in flexure, obtaining the following results.

Age Specimen	Applied load	MR (kg/cm^2)
7	3930	52.40
28	3980	53.07
Witness 28	3900	52.00

Table 5 Strengths of the 3 concrete beams without fibers
Source: Own Elaboration (2021)

The concrete beams with polypropylene fibers were tested for bending, obtaining the following results.

Age Specimen (days)	Applied load (kg)	MR (kg/cm^2)
7	3760	50.13
28	4000	53.33
Witness 28	4290	57.20

Table 6 Strengths of the 3 concrete beams with polypropylene fibers
Source: Own Elaboration (2021)

The concrete beams with cigarette butt fibers were tested for bending, obtaining the following results.

Age Specimen (days)	Applied load (kg)	MR (kg/cm^2)
7	3530	47.07
28	3940	52.53
Witness 28	4170	55.60

Table 7 Resistances of the 3 concrete beams with fibers from cigarette butts
Source: Own Elaboration (2021)

The Modulus of Rupture MR of each beam is calculated with the following equation

$$R = PL/bd^2 \tag{2}$$

Where:

R is the Modulus of Rupture, in kg / cm2
P is the load at which the beam fails, in kg
L is the distance between the supports, in cm
b is the average width of the beam, in cm
d is the average height or superelevation of the beam, in cm

The previous equation was used because the failure of the beams when tested, occurred in the middle third of the piece. If it does not fail in this way, that is, outside the middle third, another equation would have to be applied.

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Conclusions

As it could be observed in the research, the results of the compressive strength with the addition of cigarette butts and with a curing of 3 days, 82.67% of the project resistance was obtained, while after 7 days it reached a 93.37%, if compared with concrete without fibers and with concrete with polypropylene fibers, it can be seen that there were no significant variations, highlighting that the chemical components of the fibers of the cigarette butts could have influenced in terms of the results obtained.

For all the specimens (cylinders and beams) made with the fibers of cigarette butts, the objective was achieved, by obtaining concretes with f'c and MR slightly higher than those of the design or project.

It is concluded that sustainable concrete made with cigarette butts is suitable for the construction of rigid pavements of medium traffic, with a Modulus of Rupture (MR) = 45 kg / cm2.

In addition, by reusing the fibers from cigarette butts, pollution to the environment will be reduced, making a good contribution to ecosystems.

It is recommended to use the appropriate protection such as gloves and face masks, when extracting the fibers from the cigarette butts, as well as in the preparation of specimens, since due to the chemicals it contains, it can produce different reactions in the body, as well. like other infections.

The fibers of cigarette butts must be added after the cement, stone aggregates and water have been homogenized, since if it is added before adding the water to the mixture, these fibers can join each other, making it difficult to mixed, the concrete not being homogeneous and adequate, as required in the batching plants, or concretes made by mechanical and manual means.

For future research, it is recommended to make a concrete design for durability, since this will check if it meets this criterion, sustainable concrete made with cigarette butts.

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