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# Development of blended cement mortars with acoustic properties using petroleum coke

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ABSTRACT

Noise is becoming one of most important pollutants, especially in towns. Indeed, the European Community recognizes the environmental noise as one of the most important environmental problems in Europe. Therefore, there are real demands, increasing in the near future, of acoustic absorbent materials. Taking into account the conditions that these materials must present (durability, costs, noise absorption power, etc.), a new material based on petroleum coke agglomerated with cement has been developed, targeted as base for designing and construction of noise screens. Our results showed that the petroleum coke–cement system had suitable acoustic properties. Therefore, the usage of petroleum coke as acoustic absorbent material opens a new alternative, with important advantages from social and environmental viewpoints. Due to high porosity of this composite the mechanical strengths decreased with increasing coke content.



## 1. Introduction

Noise is becoming one of most important pollutants, especially in our towns. However, the society in general shows a noticeable loss of sensitivity about the problem of the acoustic contamination, considering that noise is a "tax" that must be paid for the urban development. But noise causes sleep disorders, attention and efficiency losses, changes of conduct, stress, etc. Indeed, and therefore, it can be a risk for the health.

Nevertheless, in the last years, the social awakening on the problems related to environmental noise is increasing, and the people demand a higher protection against it, especially in the housing [1–3]. In this way, these demands are reflected in the directives, rules and laws promulgated by the states. Thus, the European Commission recognizes the environmental noise as one of the most important environmental problems in Europe [4], and, consequently, many countries are promulgating laws limiting noise levels (i.e., in Spain [5]).

For the elimination or, at least, limitation of this pollutant, two different mechanisms can be defined with respect to the acoustic attenuation seen from an observer. If the sound wave collides against a hard and "even" (reflecting) surface, it will be reflected, as the light on a mirror (acoustic isolation). However, if it impinges on a material with a noticeable (open) porosity, the wave will go into the solid, its energy will be transform (dispersed) in heat and, in short, the noise will be dissipated (acoustic absorption).

In the case of an absorber, the material should have a huge open porosity, in order to get the wave going over a long and tortuous way, because of the interferences between the different fronts originated and the friction of the air molecules against the walls of the porous, since the viscous stresses are bigger than in free field.

Currently, the most usual materials for such application are mineral (rock and glass) wools [6,7]. Although they are probably the most efficient products for this purpose, the mineral wools are not exempt of drawbacks. In this way, they are less efficient in proportion as they become dirty or wet indeed. On the other hand, as they are prepared from melt silica and silicates, high temperatures and, therefore, high energy consumption is necessary for their production. Finally, although these fibrous materials are not considered toxic yet, they demean with the time, emitting fibrous (mainly) siliceous dust that at least can be suspicious of causing respiratory diseases, considering what happened with parent materials.

Petroleum coke is a material that, initially, shows interesting properties for such application, as it is particulate and usually possesses a high open porosity, at the same time that its density (real and apparent) is quite low. On the other hand, it can be cleaned with water, without any alteration of its acoustic properties. However, it needs a binder that gives it adequate mechanical properties. Obviously, the best candidate is the cement. Therefore, taking into account the conditions that these materials must

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present (durability, costs, porosity, noise absorption power, mechanical properties, etc.), we have developed a new material based on petroleum coke agglomerated by cement, targeted as base for designing and construction of noise screens.

## 2. Experimental

### 2.1. Petroleum coke

The used coke was industrial, produced in the refinery of REPSOL YPF in La Plata (Argentina). As it was wet as received, it was previously dried at 85 °C overnight. Once dry, it was crushed and sieved at <5 mm. Afterwards, it was quartered in fractions of 500 g. One of these portions was sieved in different fractions by using standard sieves, giving the size distribution of the crushed material (Table 1).

Three different measurements of the density of the particulate material were determined: apparent, water pycnometry and real (He). The apparent density was measured using a Hall's fluxometer. For the water density, a standard pycnometer and procedure was carried out, using water as fluid of known density. Finally, the real density was measured by He pycnometry [8,9], using a Stereopycnometer Quanta-Chrome, He of chromatographic quality and degasifying the sample down to 0.01 torr. The three values determined for the grain fraction between 1.25 and 2.5 mm of the carbonaceous material are shown in Table 2. From these values, it is clear that most of the porosity in the material is open, as the water density is almost the same that real one. The small difference between them can be due to the small diameter of some porous and the corresponding capillary effects.

**Table 1**
Granulometric distribution of the crushed coke obtained by sieving (manipulation losses: 0.82%).

| Sieve mesh (mm) | Retained (%) | |
|---|---|---|
| | Partial | Accumulated |
| 5.00 | 0.6 | 0.6 |
| 4.76 | 4.1 | 4.7 |
| 4.00 | 23.9 | 28.6 |
| 2.36 | 55.0 | 83.6 |
| 2.00 | 11.5 | 95.1 |
| <2.00 | 4.1 | 99.2 |

**Table 2**
Density values (apparent, water and real), in g/cm$^3$, determined for the coke used in this study (standard deviation in all the cases: 0.005 g/cm$^3$).

| Apparent density | Water density | Real density |
|---|---|---|
| 0.691 | 1.271 | 1.387 |

### 2.2. Preparation of blended cement mortars

For the preparation of the mortar, a Portland cement CEM I 42.5 R [10] was used. For the preparation of the pellets, only the fraction between 2 and 5 mm was used (selected according to the work described ahead). In order to avoid the occlusion of the porous by the cement was previously wetted by immersion in water for a day, and then let drain for 2 h. In a mixer, the cement is added to water (ratio water/cement = 0.24, w/w), being kneaded smoothly for 30 s; afterward, the coke is added, and the mixture is kneaded for 1 min more at the same intensity, plus 30 s vigorously.

For acoustic measurements (see below), the mix was poured in cylindrical Teflon molds, and then shook for 30 s; the pellets were allowed to cure for 24 h before demolding, and after that, they were immersed in water again for 1 day more. The acoustic measurements are carried out at 7 and 28 days of curing.

In the case of the pellets for mechanical measurements, they were prepared according to a modification of the standard EN 196-1/1996 [11]; for such study, several cement/coke ratios were tested (1/3, 1/2 and 1/1, w/w), maintaining the ratio 0.24 for water/cement; the mechanical measurements were carried out after 28 days of curing, on three different specimens. For comparative purposes, a standard mortar was prepared according exactly to the referred standard [11], using sand instead of coke. The aspect of the composite materials can be appreciated in Fig. 1, where they are shown after mechanical tests.

In order to check the porosity of the composite materials, the pellets were tested according to the method described in [12]. Following it, the sample is immersed in water vertically and with 2 cm of water behind; at fixed times, the pellets are weighted periodically, up to 480 h (end of the test).

### 2.3. Acoustic measurements

A standing wave and an impedance tube (Brüel & Kjaer 4206) was used (Fig. 2) to obtain the acoustic parameters (according to

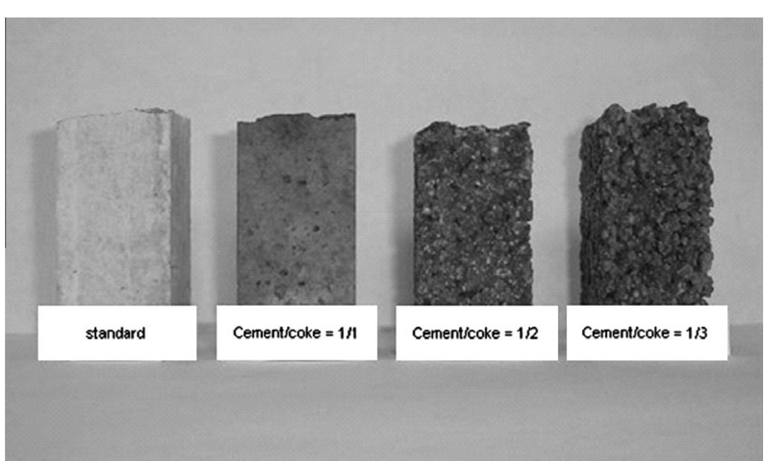


**Fig. 1.** Aspect of the composite specimens manufactured with petroleum coke and cement at three dosage degrees plus that made of standard mortar [4], after mechanical tests.