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Technical note

Potential use of cigarette filters as sound porous absorber

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ABSTRACT

Cigarette butts are a common type of litter. This paper reports an investigation of the physical properties and acoustical performance of a cellulose acetate material made from cigarette filters. Physical properties measured include porosity, flow resistivity, fiber diameter and skeletal density. The influence of smoking on these physical properties is explored. The acoustical performance of the cigarette filter derived material has been assessed according to ISO 10534–2: 1998 and compared to that of other commercial fiber materials. The comparison shows that, for a given thickness, the performance is similar or better suggesting that the material should be considered as an alternative to commercial products in building construction.

1. Introduction

Nowadays, one of the most common types of litter in the world are the cigarette butts. Euromonitor International estimated that more than 5.8 trillion cigarettes were smoked worldwide in 2104 [1]. These numbers are expected to increase more than 50% in 2025, mainly due to an increase in world population and in tobacco production [2]. This results in an enormous quantity of tonnes of toxic waste in the form of cigarette butts. This waste is not easily biodegradable. Therefore, landfilling [3] or incineration [4] of cigarette butts are not universally sustainable or economically feasible disposal methods [5] so the problem of the disposal of this kind of waste is a serious environmental problem.

Cigarette filters are mainly made of highly purified cellulose fiber, derived from wood pulp through acetylation (reacted with acetic anhydride) to the secondary acetate by hydrolysis producing cellulose diacetate fiber, commonly called cellulose acetate [5]. The photodegradation of this not biodegradable substance takes several months, and is only partial even this material is broken into smaller pieces [6,7]. Thus, recycling of this kind of waste material, a pending issue particularly in developed countries, can eliminate a substantial portion of the purchase and disposal costs for new materials or applications. Focusing on efforts to obtain more environmentally respectful new products should be the starting point for environmental sustainability. In the last years some authors have proposed some different uses for smoked butts [5,8,9].

This work shows the potential use of used cellulose acetate as sound absorbent materials, continuing the work developed by Gomez Escobar and Maderuelo-Sanz [10] for used cigarette filters. In recent years natural fibers and recycling materials are increasingly gaining attention in diversified engineering end uses instead of rock or mineral fibers, some of them having natural origin [11–13] or through the use of recycled materials as cork or rubber [14,15] to develop new and effective sound porous absorbers. Thus, the recycling of similar wastes into these new sound absorbent materials has become a viable option to be considered in building construction.

The acoustical performance of cigarette filters has previously studied by these authors, but this work offers the difference with the previous work that in this case, only the acoustical performance from the cellulose acetate, an homogeneous material where the constitution and pore structure of samples taken from different regions of a large sample may not vary considerably, was studied, while in the previous work [10], the samples studied were prepared from intact cigarette butts. It is obvious that the cellulose acetate thus studied needs to be further treated because of the different carcinogenic components that it presents (there are over 5000 identified chemicals and more than 60 known carcinogens in cigarette smoke) [16].

2. Measurements

2.1. Materials and sample preparation

The materials used in this work are cigarette filters (CFs) mainly made of an outer paper (a tipping paper often printed

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to look like cork), an inner paper wrapper (having a polyvinyl acetate emulsion to attach the outer paper and to seam the wrapper), and non-biodegradable cellulose acetate. Two different types of cigarette filters were employed, used and non-used, the former consisting of different brands and sizes collected from dry receptacles and the latter were purchased. Non-smoked cigarette filters are used as well as smoked ones to investigate the differences in physical and acoustical properties that result from their being smoked.

CFs were dried at 80 °C for 72 h in order to disinfect and to remove the humidity and then stored in sealed plastic bags. Cellulose acetate was manually separated from the outer and inner paper and was shredded into short fibers which were subsequently mixed. The authors proposed this initial treatment in order to obtain a homogeneous mixture getting more reliable and homogeneous physical properties like porosity, flow resistivity or bulk density for each tested sample. Finally, the blend was compacted between a grid and the hard back termination of the impedance tube (Fig. 1) to reach a given bulk density where no specific bonding method was used. Some authors have studied that the bonding method had little effects on the sound acoustical performance and, its impact may be indirectly included in the bulk density of the mixture [17,18].

For non-used Cigarette Filters (CFnu#n), six different bulk densities were prepared with a thickness of 14 mm. In the case of used Cigarette Filters (CFu#), 3 different thicknesses; 14 mm (CFu#n), 26.5 mm (CFu#2n) and 52 mm (CFu#4n), were studied (where n = 1–6). For each thickness six different bulk densities were prepared too. The total of different samples used in this work was 24 groups of CF with different bulk densities and thicknesses (Table 1). In order to obtain and averaged value, 4 specimens for each group were tested.

2.2. Physical properties

Fibers diameters, mass per unit area, porosity, air flow resistivity, surface impedance and sound absorption coefficient at normal incidence were measured and analysed.

Fig. 1. Photograph of samples of non-used (a) and used (b) acetate cellulose fiber from cigarette filter in the sample holder of 29 mm.

Table 1
Physical properties of used (CFu#) and non-used (CFnu#) samples tested.

Sample ID	Bulk density (kg m^{-3})	Average mass per area (g m^{-2})	Porosity	Flow resistivity (Pa s m^{-2})
CFnu#1	102.12	1440	0.974	19,201
CFnu #2	110.71	1560	0.972	20,687
CFnu #3	119.30	1680	0.970	19,582
CFnu #4	127.89	1800	0.968	22,104
CFnu #5	136.48	1920	0.965	23,541
CFnu #6	145.07	2050	0.963	24,117
CFu#1	104.04	1470	0.953	23,447
CFu #2	116.91	1650	0.947	24,002
CFu #3	127.42	1800	0.943	26,705
CFu #4	137.93	1950	0.938	27,665
CFu #5	148.44	2100	0.933	29,365
CFu #6	158.95	2240	0.929	34,201
CFu#21	89.75	2380	0.960	20,113
CFu #22	98.04	2600	0.956	21,009
CFu #23	106.43	2820	0.953	23,787
CFu #24	114.60	3040	0.949	23,587
CFu #25	122.60	3250	0.945	23,784
CFu #26	130.66	3460	0.942	28,014
CFu#41	92.61	4820	0.959	21,314
CFu #42	101.41	5270	0.955	23,170
CFu #43	109.56	5700	0.951	22,587
CFu #44	117.83	6130	0.947	23,712
CFu #45	126.82	6600	0.943	26,387
CFu #46	135.09	7030	0.940	28,207