SWITCHGRASS-BASED NOISE ABSORBING MATERIAL: CHARACTERIZATION AND MODELING

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1. INTRODUCTION

For decades, noise reduction on road construction sites has been a major issue for transportation agencies worldwide. Noise pollution is a real health concern in our modern society and frequent or permanent exposure to noise can cause irreversible health damage such as permanent hearing loss. One effective way to decrease noise in construction sites is to build sound-absorbing barrier walls. However, and in addition to have appropriate acoustic properties, the design and fabrication of such walls must comply with environmental regulations and sustainable development policies. Consequently, developing sound or absorbent barrier materials made of plant or plant residues can be regarded as an effective way to take environmental concerns into account. In this work, the potential of using *Panicum virgatum* (switchgrass), a tallgrass plant largely available in North America, as an acoustic absorbent was investigated. Thus, in this paper, the sound absorption coefficient of switchgrass-based material was assessed and modeled.

2. MATERIAL, SAMPLES PREPARATION AND TECHNIQUES

2.1. Material

Switchgrass is a tall grass plant largely present in North America and especially in Canada. It grows from rhizomes and is characterized by stems that can reach, like bamboo or sugarcane, up to 2 meters high. Moreover, its roots can be as deep as 2 meters. This plant belongs to the perennial plants family, meaning that after a 2 year growth period it can live up to 10 years. Switchgrass is actually investigated for energy production (including fuel pellets or bioethanol), soil conservation and erosion and, to a lesser extent, as feedstock for bioplastics production.

2.2. Sample preparation

In order to characterize and model the plant absorption performances, switchgrass stems were cut at various lengths (ranging from 5 to 40 mm) and were randomly stacked (figures 1a and 1b). Porosity and density measurements were performed on disc-shaped specimens (100 mm diameter by 90 mm thick).

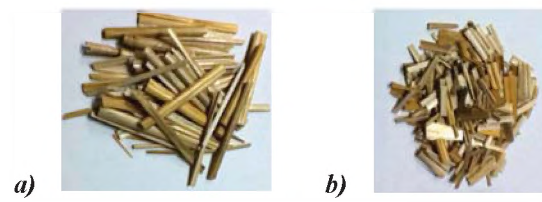

Figure 1. Randomly stacked switchgrass with stems length of: a) 40 mm and b) 10 mm

2.3. Techniques

The porosity and density were determined using a pressure mass method that was previously reported in literature [1]. It is important to mention that during the measurement, samples were not compressed, the only pressure to which they were subjected being their own weight. For all prepared specimens, absorption coefficient was obtained according to the ASTM E 1050-98 method whilst the absorption tests were obtained following testing made on a 100 mm diameter impedance tube (Brüel & Kjær Type 4206) using 90 mm thick samples. Besides, all the measurements were performed in the frequency range of 200 to 2,000 Hz which corresponds, somewhat well, to the frequency range of noise in construction sites.

3. RESULTS AND MODELLING

3.1. Effect of stems length on the sound absorption coefficient

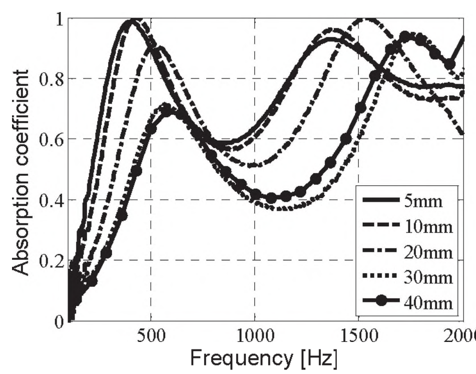

Figure 2. Sound absorption coefficient vs. frequency of randomly stacked switchgrass with various stem lengths.

Figure 2 depicts absorption coefficient as a function of frequency for randomly stacked switchgrass with stem lengths varying from 5 to 40 mm. As can be seen, absorption coefficient increases and the maxima shifted toward lower frequency as stem length decreases.

3.2. Modelling

3.2.1. Johnson Champoux Alard's model (JCA)

In order to simulate the sound absorption coefficient *versus* frequency of the randomly stacked switchgrass stems, the Johnson Champoux Alard model (JCA) was used [2]. The JCA model requires 5 parameters in order to calculate the sound absorption: porosity, airflow resistivity, tortuosity, viscous and thermal characteristic lengths. These parameters were determined experimentally.

Table 1. Parameters of Johnson Champoux Alard's model

Stem length (mm)	Porosity	Resistivity ($N.m^{-4}.s$)	Lv (μm)	Lth (μm)	Tortuosity
5	0.77_5	3660	123.7	480.6	2.3_9
10	0.78_6	1359	153.2	688.5	2.5_0
20	0.81_4	150	258.6	905.1	2.3_2
40	0.84_6	1	441.5	1293.5	2.1_0

3.2.2. Kim *et al.* 's model

To simulate the sound absorption of porous concrete, Kim *et al.* have proposed a model based on the theory of spheres packing [3]. This model takes into account geometrical parameters of spheres, the porosity and the space between two adjacent layers of spheres (compactness). In our case, this approach can be applied as far as one can approximate the shape of switchgrass stems by a sphere. This assumption is verified as far as width and length of stems are in the same order of magnitude. Thus, for this study, such a model can reasonably be applied to short stem lengths such as 5 mm.

Table 2. Parameters of Kim *et al.* 's model

Porosity	Radius of aggregates (mm)	Diameter of apertures (mm)	Shape of aggregates	Thickness (mm)
$0{,}77_5$	1	0.5	Packed lattice (k=1)	90

3.2.3. Comparison

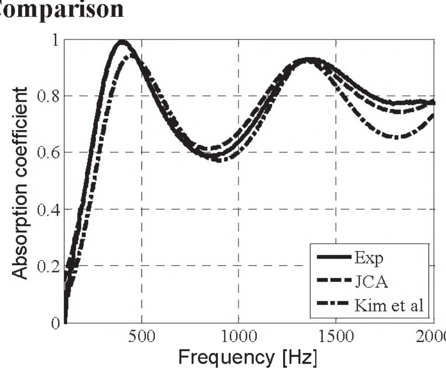

Figure 3. Comparison between sound absorption obtained using JCA and Kim et al. models and experimental data

Figure 3 compares the sound absorption obtained with the JCA and Kim *et al.* models to experimental data for the 5 mm length stems randomly stacked switchgrass. As can be seen, both models show similarities with the empirical values; however the JCA model seems to be better as it matches the measured absorption coefficient over the whole range of frequency.

3.2.4. Robustness of models

To validate parameters of both models and consequently to test their robustness, all parameters were kept constant and a simulation was performed on a 100 mm diameter and 44 mm thick sample. Then, the sample was elaborated and its absorption coefficient was assessed and compared to simulated values (figure 4). As can be seen, the simulated and evaluated absorption coefficients match which allows validation of the modeled parameters. Again in that case, the JCA model seems to be better than Kim *et al.* 's model.

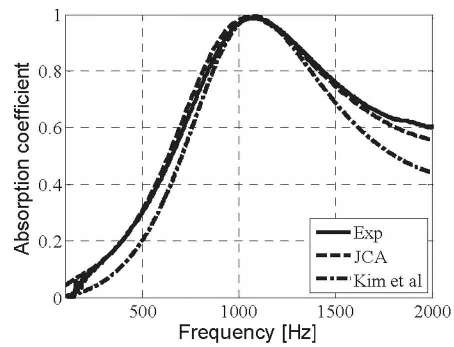

Figure 4. Validation of JCA and Kim's parameters models

4. CONCLUSION

In this paper, the potential of using switchgrass as noise absorbent material was investigated. Thus, samples of randomly stacked switchgrass stems of various lengths were elaborated and characterized. Two models were used to simulate the sound absorption coefficient and compared to experimental data. The Johnson Champoux Alard model was shown to be the most reliable model which allows the assumption that it can be used to find the optimal thickness for the design of switchgrass-based sound absorbing panels.

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