Sound Absorption with Green Materials

Amelia Trematerra [1, a)], Ilaria Lombardi [1, b)]

[1]Department of Architecture and Industrial Design – Università della Campania "Luigi Vanvitelli" – Borgo San Lorenzo 81031 Aversa (Italy)

[a)] Corresponding author: liatrematerra@libero.it
[b)] ilaria.lombardi@studenti.unina2.it

Abstract. Green materials are a valid alternative to traditional materials that are by-products of processing oil. At the end of their useful life, green materials can be disposed of without polluting the environment. They are now being used in the construction and automotive industries. While, studies are currently being carried out in the aviation sector on the use of green materials for non-structural components of airplanes. Green materials can be used to improve the acoustic comfort inside buildings as well as mitigate reverberation, echoes effects and reduce the transmission of noise between rooms. In this paper, the acoustic measurements of the properties of green materials are reported. The absorption coefficient of samples of the materials were measured in the frequency range from 200 Hz to 2,000 Hz with an impedance tube, with the flow resistance being measured.

INTRODUCTION

Green materials are "sustainable materials" [1, 2] as well as a valid alternative to traditional materials that are by-products of processing oil. At the end of their useful life, green materials can be disposed of without polluting the environment. They are now being used in the construction and automotive industries. While, studies are currently being carried out in the aviation sector on the use of green materials for non-structural components of airplanes. Green materials can be used to improve the acoustic comfort inside buildings as well as mitigate reverberation, echoes effects and reduce the transmission of noise between rooms. They are biodegradable, recyclable, renewable, widely available and have a relatively low cost manufacturing process. This paper reports the acoustic measurements of green materials used in the field of architectural acoustics as absorbent materials, with the reverberation time inside rooms being controlled. Traditional sound absorbing materials (glass wool, rock wool, polyester, polyurethane foam) can be subsequently replaced [3, 4]. The acoustic properties of green materials have been analyzed. Green materials can be easily found in the countryside, with them including giant sweet water reeds, hemp, straw, kenaf, wood, cork and sheep wool. The materials were cut, dried, crushed and then transformed into panels. When the materials are crushed, they have a high porosity with good thermal insulation and sound absorption properties. The basic element for a material to be sound absorbing is porosity. Sound waves can enter the material, with the relative sound energy being dissipated into heat, thus allowing for sound absorption and a suitable absorption coefficient value. The absorption of sound is a dissipative mechanism phenomenon and for this reason, sound-absorbing materials should be composed of granular or fibrous materials. Materials with these characteristics are ideal for absorbing sound. The green material was dried, crushed and then put into jute sacks so as to realize uniform sound absorbing panels. Several authors have realised green material panels and tested them in classrooms. This type of material is becoming more widespread in architectural acoustics applications. Natural fibers are competitive materials thanks to their good mechanical properties, easy processing, high stability, occupational health benefits, widespread availability, low price, and reduced environmental impacts of their production. A sustainable material with good acoustic properties is wool. It is a renewable and recyclable raw material which is obtained from the shearing of sheep. It is an environmentally friendly textile fibre, since it does not require any energy to be produced. The thermal properties of wool were well-known. Thanks to its special microstructure, sheep wool is an excellent alternative to mineral fibres for thermal and sound insulation.

METHODOLOGY

The sound absorption coefficient at normal incidence was determined according to the procedure described in the ISO 10534-2 [5, 6, 7]. This method allows to measure the acoustic parameters by using small samples that are easy to assemble and disassemble. The measurements were carried out using a Kundt's tube, with the following features: internal diameter of 10 cm (corresponding to a lower limit of 200 Hz, an upper frequency limit of 2,000 Hz), length of 56 cm, with two ¼'' microphones. To limit the effects due to the irregularities in the samples, four different measurements were taken for each sample, stirring and inserting melted material in the tube every time [8]. The resulting absorption coefficient values are the average of the four acquisitions. Figure 1 shows the impedance tube (Kundt's tube) for the normal sound absorption coefficient measurement.

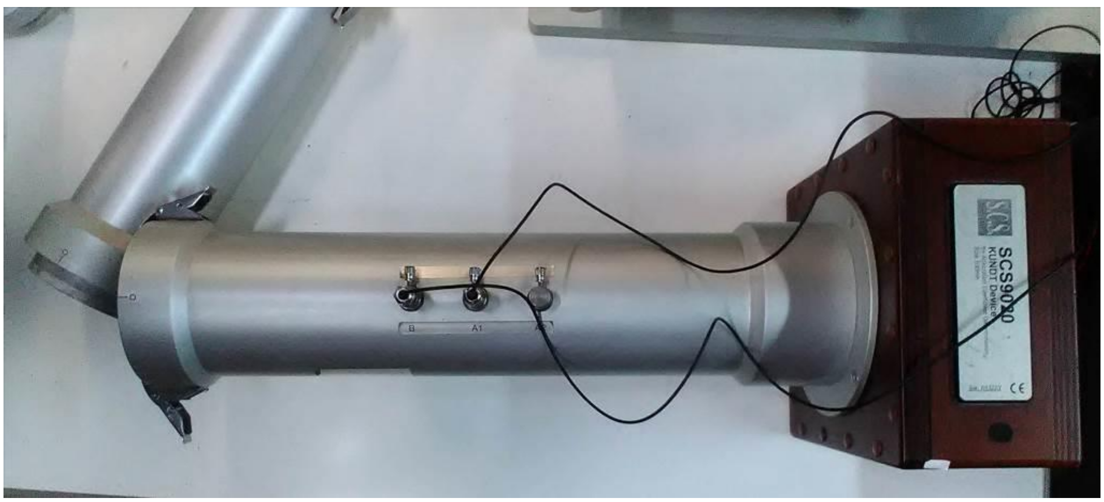

Figure 1. Impedance tube for the normal sound absorption coefficient measurement.

The airflow resistance was measured. In these experiments, the measurements were carried out according to the alternate flow method at a frequency of 2 Hz. Using a device consisting of a cylindrical tube, closed with a sample of the tested material. A piston system, moved by a rotating cam, created the alternate air flow inside the tube and a pressure microphone was used to measure the pressure disturbance. For each sample, measurements were taken with four different cams, corresponding to four air speeds (0.5, 1.0, 2.0 and 4.0 m/s) in the measuring tube. Furthermore, the porosity was measured. The porosity Y is defined as the ratio between the volume occupied by the air (Va) and that occupied by all the material (Vm). The porosity is determined knowing the density of the material prior to the shredding and the density of the granular material [9, 10, 11]. The porosity is determined knowing the density of the material prior to the shredding and the density of the granular material; ρm (kg/m^3) is the apparent density of the material, ρsolid (kg/m^3) is the density of the material of which the skeleton is made.

MATERIALS

The absorption coefficient values of four green materials tested by several authors are reported. The materials are cane, hemp, kenaf and sheep wool. All the material samples had a thickness equal to 40 mm. The average value of the absorption coefficient measured at normal incidence in the frequency range 200 Hz – 2,000 Hz was analyzed.

Figure 2 shows the trend for cane, with the average measured resistivity being R1 = 840 (+/- 100) Rayl/m, the average porosity Y = 0.30, the density 450 kg/m^3. Figure 3 shows the trend for hemp, with the average measured resistivity being R1 = 1400 (+/- 170) Rayl/m, the density 50 kg/m^3. Figure 4 shows the trend for kenaf, with the average measured resistivity being R1 = 3500 (+/- 240) Rayl/m, the density 100 kg/m^3. Figure 5 shows the trend for sheep wool, with the average measured resistivity being R1 = 2100 (+/- 150) Rayl/m, the density 40 kg/m^3. The materials tested have good absorption coefficient values at the medium and high frequencies. These materials can be used to replace traditional absorbent materials such as polyurethane, foam or PET [12, 13, 14]. Cork sheets with a thickness of 1.5 mm and sheep wool fabrics can also be used as sound-absorbing materials. When a thin flexible panel is placed at a distance from a rigid wall, it absorbs a part of the incident sound energy. The sound absorption is highly influenced by the distance of the panel from the rigid rear wall, in a way that the maximum absorption results for a cavity equal to λ / 4 (defined λ the sound wavelength). This means that a greater depth of the cavity moves the absorption towards the low frequencies. Figure 6 shows the trend for the sheet of cork with thickness of 1.5 mm and back cavity of 5 cm. The use of thin cork panels, mounted at a distance appropriate to a rear rigid wall can be used for the acoustic correction of closed environments. This can adequately accommodate the acoustic comfort conditions and make environments aesthetically pleasing, thus expanding the use of the cork in interiors. In this manner also for the sheep wool. Woven wool (thin felt) for the realization of tapestries, and tapestries created with 1.5 mm diameter wool wires mounted at a distance from the rigid termination of the impedance tube [15]. Figure 7 shows the trend of absorbent coefficient in this configuration.

CONCLUSIONS

This paper presented the acoustic properties of some sustainable materials. These materials have good absorbent coefficients at medium and high frequencies. Whereas, at lower frequencies, these materials like traditional ones (polyester, foam, PET) generally do not good absorbent frequency values. To increase the absorption at low frequencies, thin cork panels with a thickness of 1.5mm or sheep wool fabric can be used. These materials when mounted at an appropriate distance from a rear rigid wall can absorb sounds at frequencies depending on the depth of the rear recess, if the cavity increases, the sound field is absorbed at low frequencies, if the cavity is reduced, the sound absorption moves to the high frequencies. The wide availability of the materials reduces the production and realization cost of the panels. However, the most important factor is that these materials are completely recyclable.

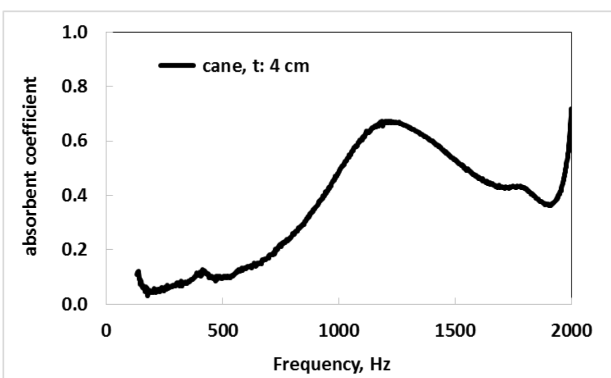

Figure 2. Cane

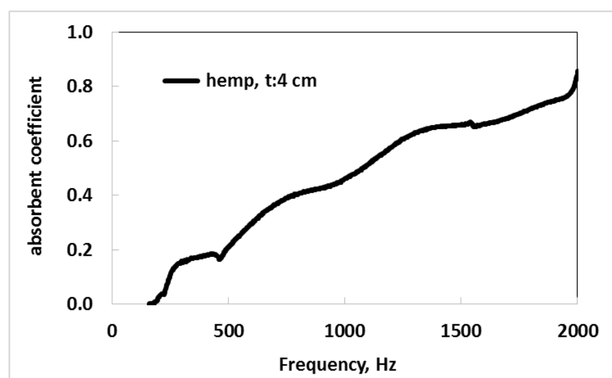

Figure 3. Hemp

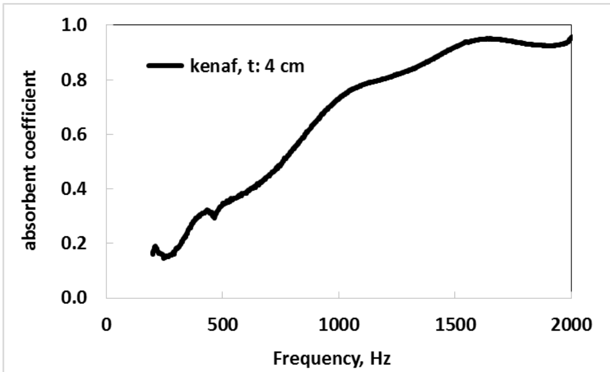

Figure 4. Kenaf

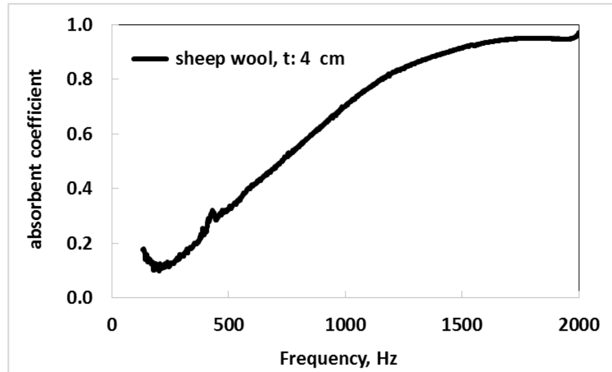

Figure 5. Sheep wool

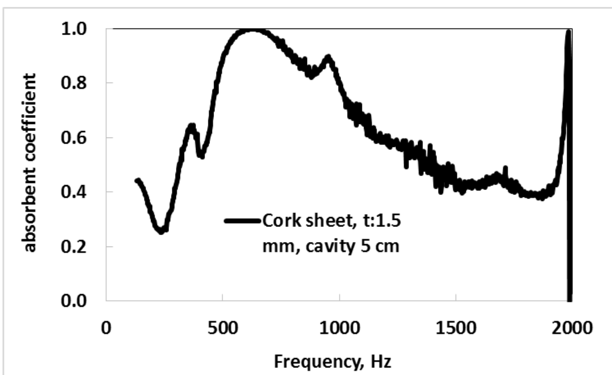

Figure 6. Cork mounted at a distance of 5 cm from a back wall

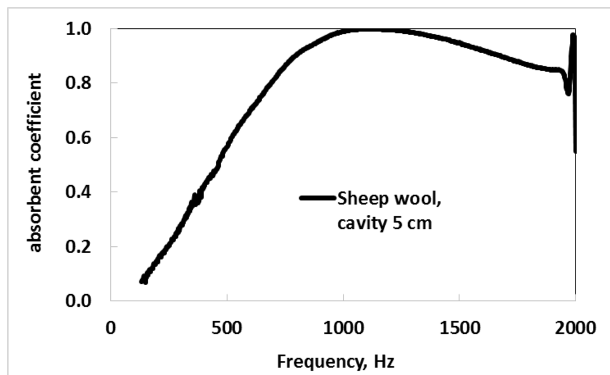

Figure 7. Sheep wool mounted at a distance of 5 cm from a back wall

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