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Use of Green Material for Acoustic Correction inside Rooms

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The green materials are products obtained by the transformation of materials of vegetable origin; they have the advantage that at the end of their useful life, they are scattered in the environment without causing damage. In this work the green material considered and used for acoustic application is made from giant reeds of sweet water (arundo donax). The giant reeds have been cut, dried and shredded, and a loosened granular material has been obtained, which is very porous and it presents good characteristics both in thermal isolation and in acoustic absorption. This paper shows giant reeds application in the room acoustic. Panels with giant reeds shredded were made and they were used in a classroom for the reduction of reverberation time.

Keywords: *acoustic, green material, reverberation time.*

1. Introduction

In the last years the attention for both the energy savings and the acoustic correction of rooms has been growing. This attention is due to the adoption of some recent European directives, which require the reduction of greenhouse gas emissions to be achieved by the energy saving means and tax legislation that allows the recovery of part of the sums invested in the improvement of energy efficiency of buildings. The materials used for energy saving and for the correction of room acoustic are primarily derived from the processing of petroleum products, but lately it has spread attention towards the use of sustainable materials, i.e. materials that towards the end of the their useful life can be disposed of without polluting the environment. The green materials are products obtained by the transformation of materials of vegetable origin; and they have the advantage that at the end of their useful life, they are scattered in the environment without causing damage. Actually the green materials used are kenaf, hemp, wood, juta, but there are also green material obtained from sheep's wool. In this work the green material considered and used from acoustic application is made from giant reeds of sweet water (arundo donax). The giant reeds of sweets water have been cut, dried and shredded. A loosened granular material has been obtained from the shred, which is very porous, and it presents good characteristics both in thermal isolation and in acoustic absorption. To evaluate the loosened granular material acoustic absorption characteristics, some specimens were created with a thickness of 4.0 and 8.0 centimeters. An impedance tube ("Kundt's tube") was used to measure the absorbent coefficient values in frequency function in the range from 200 Hz to 2.0 kHz at normal incidence. The specimens absorbent coefficient values are good at the frequency over 500 Hz. The loosened granular material was put in jute sacks, so thin panels with an average thickness of 4.0 centimeters were produced; in this manner completely "green" panels are obtained. To evaluate the panels' acoustic efficiency, a room with an high reverberation time was considered. The reverberation time is the acoustic parameter considered to estimate the panels' acoustic properties (the reverberation time is defined as the time necessary, when a sound source is interrupted, the sound level to fall at 60 dB). Initially the reverberation time, when the room is empty and with the walls in smooth plaster, was measured and it was about 3.0 seconds; then in the same room the panels were installed and successively the reverberation time reduction was measured (it was about 1.5 seconds). The reverberation time with the panels installed decreased enough. The green panels produced from giant reeds of sweet water (arundo donax) suitably crushed, can be used for a good acoustic correction of rooms.

2. Methods

The giant reeds of sweet water (arundo donax) grow very quickly, especially near rivers and lakes in wetlands. In the south of Italy, when the giant reeds grow, they become a problem because large areas are invaded by them and the crops are damaged. The giant reeds usually reach 6 m in height and a diameter of 2–3 cm, the leaves are alternate, gray-green, 30–60 cm long and 2–6 cm wide. In this paper the application of the giant reeds of sweet water in the acoustic field is reported. In this case the giant reeds were cut, dried, crushed and assembled to obtain acoustic panels for the room acoustic correction. Fig. 1 shows green giants reeds near a river, while Fig. 2 shows the crushing operation with a small mill. A granular material is obtained by the crushing operation.

Fig. 1. *Giant reeds of sweet water (arundo donax)*

Fig. 2. *Crushing operation with a small mill*

Fig. 3. *Average dimension of the crushed material*

In this study the shredded material represents three types: (1) solely wooden parts (average size of a length of 40 mm, width 10 mm and thickness of 3.0 mm); (2) mixed composed of wooden parts and the cortex with varying dimensions (the bark comes from the outer coating of the giant reed tuber and for the speedy shredding operation will not be separated); (3) only bark parts. Fig. 3 shows the average dimension of the crushed material. The shredded material is a loosed granular and it presents good sound absorption characteristics, in fact the arrangement of the material allows the formation of cavities of air within which the sound waves can propagate and be attenuated; the attenuation of the incident sound is thickness, porosity and resistance to air flow function. From shredding operations were obtained the following types of materials: mixed (composed by wood and bark), only wooden part; only bark.

3. Acoustic measurements

To verify if the crushed giants reed have good acoustic properties, especially as sound absorbent material, same samples were made. The acoustic properties of the material were measured: the absorption coefficient at normal incidence, the porosity and the resistance to air flow. For the measurement of the absorption coefficient at normal incidence a impedance tube ("Kundt's tube") was used (Fig. 4); the measurement was performed in accordance with the ASTM E150-98 "*Standard test method for impedance and absorption of acoustic material using a tube, two microphones and to digital analysis system*". The "Kundt's tube" has the following dimensions: the inner diameter is 100 mm, length is 560 mm, and the distance between the two measuring microphones is 50 mm. The measurement range frequency is 200 Hz – 2.0 kHz. The resistance to air flow was measured with the method of the alternating flow ina accordance with the EN 29053 - ISO 9053: "*Acoustic - Materials for acoustical application. The determination of air flow resistance*" using the cam system that generates a sinusoidal air flow at the frequency of 2.0 Hz (Fig. 5). The loose granular material is put in the sample holder (Fig. 6). The porosity was obtained, using a calibrated test tube and a precision balance. Using the measures of the volume and weight of the shredded material its density value (ρ_T) is obtained; and in a similar way we obtain the density of the non-material (ρ_P) and calculate the porosity Y:

$$Y = (1 - \rho_T / \rho_P). \qquad (1)$$

Table 1. *Acoustic properties*

Loosed granular material	mixed	only wooden part	only bark
Resistivity, Rayl /m (x10^3)	0.85	1.10	0.80
Porosity, Y	0.45	0.35	0.80

Table 1 shows the results of measurements of the flow resistance and the porosity for the three types of the materials under test. These values are obtained from the average repeated measures on four different specimens made by placing the loose material in the sample holder with a thickness of respectively 40 mm and 80 mm. The low values of the flow resistance are due to the fact the materials are not compressed during the measurements. Fig. 6 shows the loose material in the sample holder.

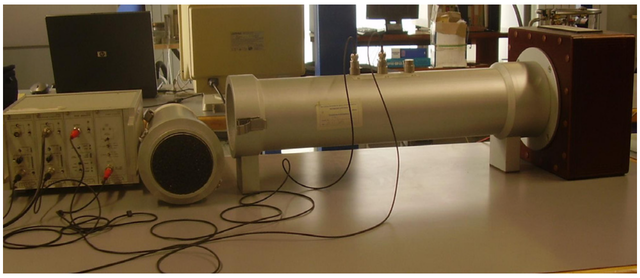

Fig. 4. *"Kundt's tube" for the absorbent acoustic coefficient measurement at normal incidence*

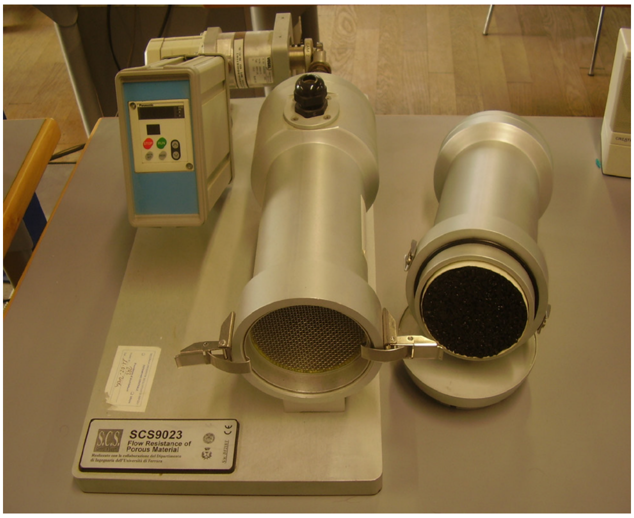

Fig. 5. *Air flow resistance measurement system, at alternate frequency of 2.0 Hz*

Fig. 6. *Loose material in the sample holder (only wood part)*

Fig. 7, Fig. 8 and Fig. 9 show the average values of the absorbent coefficient (alfa) measured at normal incidence by the "Kundt's tube" for thickness of 40 mm and 80 mm. Fig. 7 shows the of absorbent coefficient for the mixed material; Fig. 8 shows the of absorbent coefficient for the bark material; Fig. 8 shows the of absorbent coefficient for the only wood material.

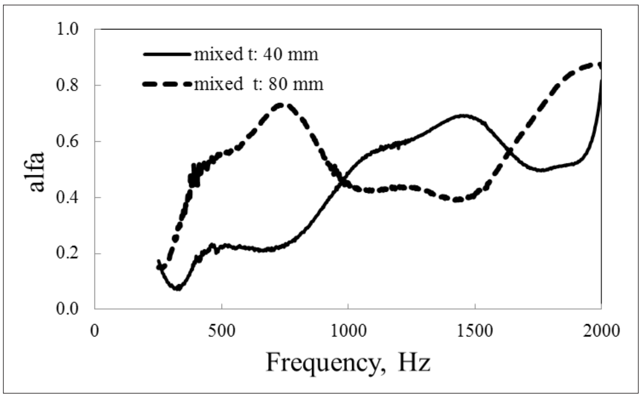

Fig. 7. *Absorbent coefficient at normal incidence (alfa) in frequency function by the "Kundt's tube" for the mixed material, with thickness 40 mm and 80 mm*

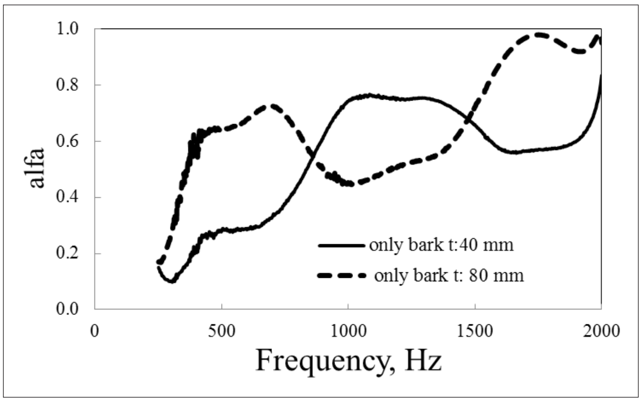

Fig. 8. *Absorbent coefficient at normal incidence (alfa) in frequency function by "Kundt's tube" for the only bark material, with thickness 40 mm and 80 mm*

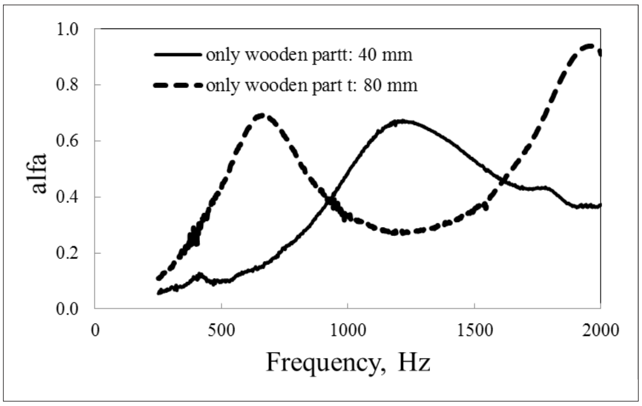

Fig. 9. *Absorbent coefficient at normal incidence (alfa) in frequency function by tube of "Kundt's tube" for the only wood material, with thickness 40 mm and 80 mm*

The results of the acoustic measurements made with the "Kundt's tube" confirm the possibility to use the giant reeds (arundo donax), suitably comminuted and of an adequate thickness and grain size, for acoustic application especially for the rooms acoustic correction. The specimens of thickness 40 mm and 80 mm present a good value of the absorption coefficient at the medium frequencies, showing a trend similar to the values of the absorption coefficients of the loose gravel. The foliage presence (Fig. 7 and Fig. 8) leads a reduction of the absorption coefficient at the medium and low frequencies. While the material with the only wooden part (Fig. 9), shows a more regular absorption coefficient trend.

4. Acoustic applications

For acoustic applications, absorbent panels were made using the mixed material, with thickness of 40 mm, because it has a good absorbent coefficient. The loose material was been inserted in jute sacks, so a layer of sound absorbing porous material was obtained (Fig. 10). The jute bags were mounted in wooden frames and covered with a colored jute layer. The jute bags are covered by jute layers for two reasons: the color panels are nice to see, and the jute layer has large mesh and it is acoustically transparent. To verify the absorbent panels' acoustic performances a full scale test was made. A university classroom of the Faculty of Architecture in Aversa (Italy) was chosen. The classroom is characterized by an high reverberation time, and the walls are made of smooth plaster; the plan dimensions are: 9.0 m length, 5.0 m width, and the average height is about 5.0 m (Fig. 11 and Fig. 12), the classroom's volume is 240 m^3.

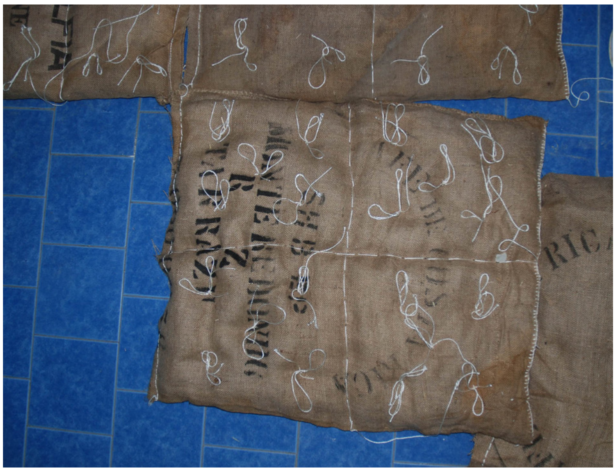

Fig. 10. *Jute sacks in which the loose material is inserted to obtain a layer of sound-absorbing porous material; the average thickness is 40 mm*

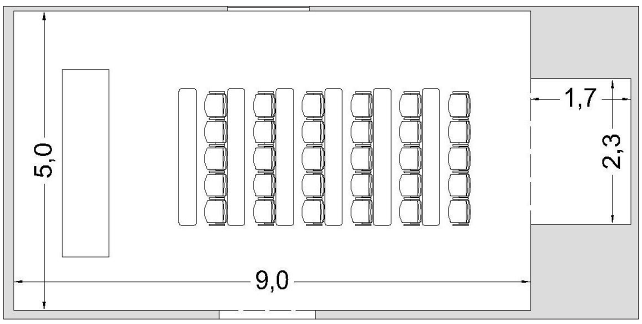

Fig. 11. *Classroom plan with dimensions*

In the classroom there are thirty hard chairs and six rows of hard tables; the students seating area is 5.30 m x 2.50 m. The acoustic parameters were measured in empty classroom in two different configurations: with the walls smooth, and after the introduction of about 15 square meters of the sound absorbing panels; Fig. 13 shows the absorbent panels installed in the classroom. The acoustic parameters were measured in accordance with EN – ISO 3382, with a measurement microphone connected to a laptop PC through the interface 01 dB Symphonie; the source was an omnidirectional sound source feed with an MLS signal. Fig. 14 shows the sound source in the classroom in the teacher's position and the measurement microphone. The measurement microphone was placed in eight different points, to obtain an average value of the acoustic parameters; the height of measurement microphone from the floor was 1.6 m.

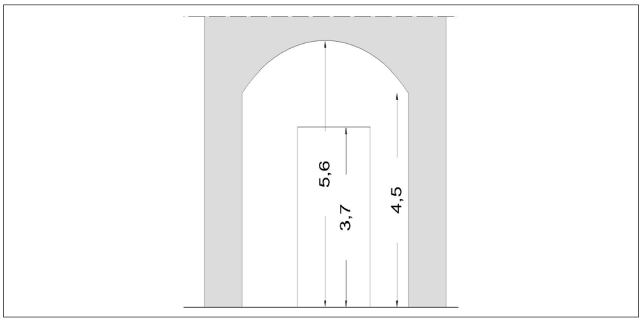

Fig. 12. *Classroom section, with height dimensions*

Fig. 13. *Sound absorbent panels installed in the classroom during the test*

5. Results

Objective acoustical parameters are considered to evaluate the panels' acoustic performance. These parameters are measured in agreement to EN ISO 3382 "*Acoustics: Measurement of the reverberation time of rooms with reference to other acoustical parameters*", and they are: the reverberation time RT30 (measured in seconds) evaluated over a 30 dB decay range (from -5 to -35 dB), using linear regression technique, it is used to determine how quickly sound decays in a room, for a good speech understanding in a classrooms RT = 1.0 s. The EDT parameter (Early Decay Time, measured in seconds) is the reverberation time, measured over the first 10 dB of the decay, this gives a more subjective evaluation of the reverberation time. The definition D_{50} is defined as the ratio of the early received sound energy (0–50 ms after direct sound arrival) to the total received energy, for a "good" listening room from a speech-intelligibility perspective has D_{50} >0.50. The RASTI (rapid transmission index) method involved measurement of the reduction of a transmitted test signal representative of the human voice. The advantage of RASTI in respect of other measurements methods is that it can be quickly evaluated without speakers or listeners, the RASTI is a value between

0 and 1 (0 is a bad speech understanding, 1 is good speech understanding). Fig. 15 and Fig. 16 show the trend of the reverberation time (RT) and of the EDT for the classroom with the walls smooth (without sound absorbing panels) and after with the introduction of the sound absorbing panels. With the insertion of the panels the average value of the reverberation time was significantly reduced (circa 1.0 second). Fig. 17 shows the trend of D50 (definition) in the same conditions; the measured value of D50 increases with the insertion of the sound absorbing panels. The average RASTI values are: for the classroom with smooth walls 0.40, for the classroom with sound absorbing panels 0.50. The intelligibility increases with the insertion of the sound absorbing panels.

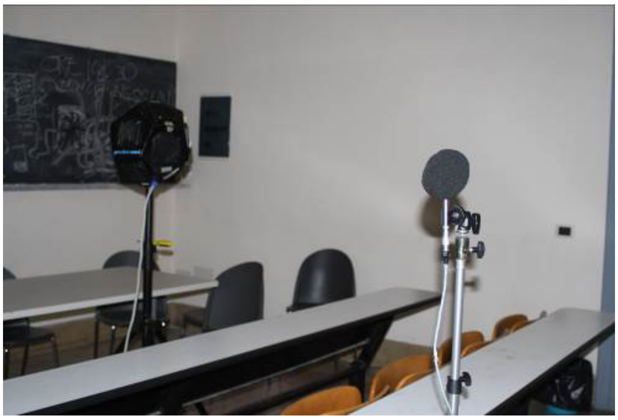

Fig. 14. *Sound source in the classroom, with the measurement microphone*

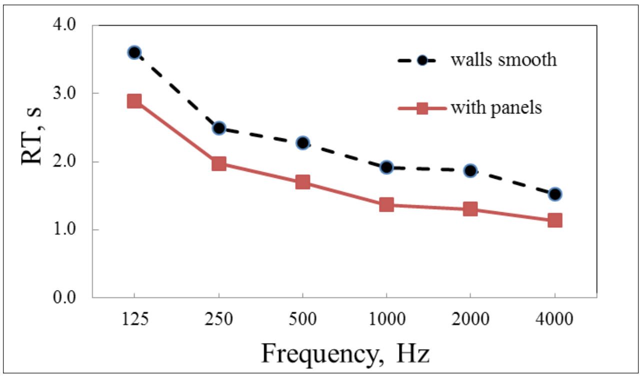

Fig. 15. *Average value of reverberation time, with the walls smooth (dotted line), and with the sound absorbing panels (continuous line)*

6. Conclusions

This paper shows that the giant reed of sweet water (arundo donax) if properly shredded can be used as a good sound absorbing material and it can be used easily for architectural acoustics application, especially the room acoustic correction (reverberation time control). The insertion in jute bags and the realization of sound absorbing panels with different colors are aesthetically acceptable. The wide availability of giant reeds reduces the cost of production and realization of the absorbent panels. The important factor is that the material is completely recyclable.

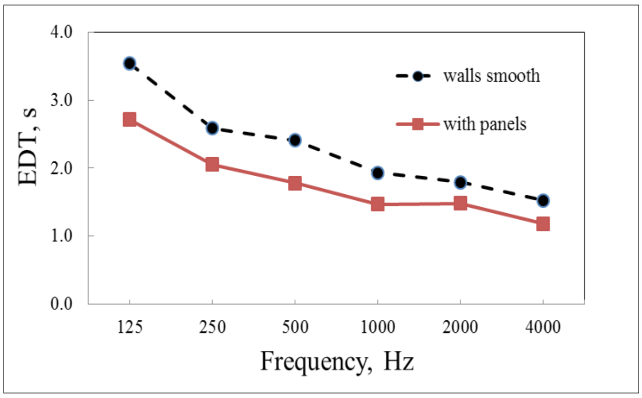

Fig. 16. *Average value of EDT, with the walls smooth (dotted line), and with the sound absorbing panels (continuous line)*

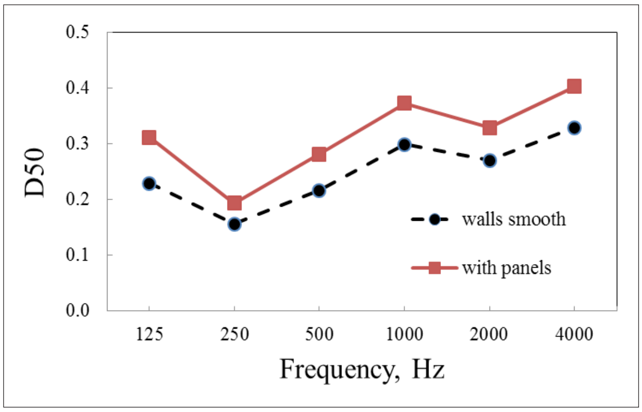

Fig. 17. *Average value of D50 (definition) with the walls smooth (dotted line), and with the sound absorbing panels (continuous line)*

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