DEVELOPMENT AND ACOUSTIC CHARACTERIZATION OF PANELS MANUFACTURED FROM VEGETABLE FIBERS

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Abstract. *In a time when high noise levels are part of people's daily lives, the necessity to control these levels is not only evident, but providential. Noise pollution is, after air and water pollution, the problem that most affects people. Acoustic devices such as panels, barriers, etc., when of high efficiency, generally, are of difficult acquisition due to high costs, making, in many cases, their use impracticable, mainly considering limited budget small-sized companies. Thus, alternative solutions, starting with new acoustic materials that are less costly and have satisfactory performance, emerge as a great option. Considering the global environmental trends, the use of vegetable fibers is a great opportunity to aggregate value, and technological development for agricultural producing countries, like Brazil. Beyond that, such fibers are easy to obtain, exist in abundance, are non toxic and derive from renewable sources. This work will present the methodology of development of acoustic panels made from vegetable fibers (açaí, coconut, palm and sisal) and a binding agent based on acrylate and water, as well as the methodology used to characterize them acoustically on a scale model reverberant chamber, based on ISO 354/1999. These panels are made of pressed layers of fibers interspersed with layers of binding agent. The fibers are extracted, washed, dried, and treated when necessary, while the binding agent is obtained commercially. The panels sound absorption data are obtained through measurements of reverberation time using the noise interruption method. Comparison of results for alternative and conventional material based panels allows the conclusion that the acoustical performance shown by some newly developed panels are very satisfactory, since their sound absorption coefficients are higher than those presented by conventional materials in most of the frequency range.*

Keywords*: Noise pollution; Alternative solutions; Vegetable fibers; Acoustic panels*

1. INTRODUCTION

Noise pollution is, after air and water pollution, the problem that most affects people. Those people, when subjected to high noise levels, may be physiologically and/or psychologically injured, may present stress, mental and emotional difficulties, and even progressive hearing loss, frequently irreversible. In other words, noise is part of peoples' daily lives. So what was formerly restricted to occupational situations today is seen as a source of physical, psychological and social problems (Andrade, 2004).

According to World Health Organization (Moço, 2007), in 2007, 10% of world population (more than 600 million people) already had some degree of hearing loss. In Brazil, this number was estimated at 15 million people, and according to IBGE (Brazilian Institute of Geography and Statistics) 350 thousand Brazilians had severe deafness, not being able to hear anything without hearing aids.

The problems caused by noise excess, not only at workplace, but in any environment, are known for many people, but little is done to reduce noise levels to appropriate values. Noncompliance or unknowledgement of existing national standards related to noise (NR 6, NR 7, NR 15, NR 17, NBR 10151, NBR 10152), lack of awareness of employees and employers, lack of national mobilization campaigns, high costs for adequacy of working environments to satisfactory levels, among others, are factors that aggravate the current condition of the country.

Acoustic devices such as panels, barriers, etc., when of high efficiency, generally, are of difficult acquisition due to high costs, making, in many cases, their use impracticable, mainly considering limited budget small-sized companies. Furthermore, the existing materials on the market either insulate or absorb sound waves, however with different efficiencies, i.e., the material which presents high acoustic insulation characteristics, has almost no sound absorption capability, and vice versa. Other materials present neither acoustic insulation nor sound absorption characteristics (e.g. soft and waterproof plastics).

Aiming to minimize the degree of environmental pollution, noise control techniques (active, passive and combined) have been developed over the years. Techniques which are generally specific to each case and that, currently, bump into one aspect, namely, the cost, which has to be considered in face of the benefits obtained through those techniques (Bastos, 2007). Therefore, alternative solutions, starting from new acoustic materials that are less costly and have satisfactory performance, emerge as an excellent option.

2. VEGETABLE FIBERS

Fiber materials are very thin and elongated, like filaments, which may be continuous or cut. They are also very important as a raw material for manufacturing, can be spun for the formation of wires, lines or ropes or placed in blankets, for the production of paper, felt or other products. The fibers used in manufacturing are classified according to their origin, which may be natural (animal or vegetable), or synthetic. Natural fibers are extracted directly from nature, the most common being cotton (CO), wool (WO), silk (SK), flax (CL) and ramie (CR). In this work it will be used sisal, palm, coconut and açaí fibers, which are easy to obtain, not toxic, derive from renewable sources, are of low cost and exist in abundance in the region where the work was developed.

The use of vegetable fibers rather than synthetic fibers is taking greater proportions due to the high production costs of synthetic fibers such as fiberglass, for example, reflected in high energy consumption and degradation time. Additionally, vegetable fibers are biodegradable, lighter, cause smaller environmental impact and have lower density (Mattoso et al., 1996).

It is already known that some vegetable fibers, in the form of panels, have satisfactory acoustic absorption characteristics. The required infrastructure and procedures to determine properties of acoustic panels have been developed (Mafra, 2004), especially considering coconut fibers panels (Vieira, 2008); acoustic tests of partitions made from regional fibers (coconut and açaí fibers) and plywood were performed on scale model germinated reverberation chambers in order to quantify their sound insulation capability, obtaining satisfactory results and proposing to follow tests with other fibers (Toutonge, 2006); comparisons between panels of coconut fibers of different thicknesses and densities and acoustic absorbing materials, in relation to their sound absorption coefficients, were made on scale model reverberation chamber, noting that the panels in certain frequencies, had superior performance to the conventional acoustic materials (Guedes, 2007).

Apart to promoting noise control indoors, these panels have economical importance for the region where the fibers are extracted, since they provide an increase in the income of the people involved with these activities. A car seat made from vegetable fiber, for example, requires at least four times more labor than one made of foam (Marroquim, 1994).

This work presents a methodology of development of the panels made from vegetable fibers and the necessary procedures to characterize them acoustically. It also makes a comparison between the panels of vegetable fibers and acoustic conventional materials, with respect to their sound absorption coefficients.

3. METHODOLOGY

3.1. Materials

- Palm, coconut, sisal and açaí fibers;
- Agent binding, based on acrylate and water;
- Microcomputer;
- Frequency Analyzer;
- Diffuse field microphone;
- Calibrator;
- Scale Model Reverberant Chamber;

3.2. Obtainment and Treatment of the Fibers

The palm fibers used in this study were obtained through donations from Companhia Refinadora da Amazônia. As those fibers still showed a considerable residual content of palm oil, inherent to the process of extraction, which accelerates the degradation of the fibers and appearance of fungus, the fibers were washed with industrial neutral detergent to remove the oil, and left to dry under the sun. Açaí fibers were acquired through an extraction process developed specifically for this purpose, after the pit are obtained, already without pulp, previously washed and dried. The sisal fibers were acquired commercially. The coconut fibers, already modified by industrial processes, were purchased from Amazon Fibers Company (POEMATEC).

3.3. Development of the panels

The methodology used for the development of the panels considers two main aspects: the compatibility of the fibers in relation to the binding agent used, and the treatments (chemical, thermal, etc.) that the fibers must receive, when necessary, to be converted into panels.

The related processes are shown below (see Figure 1).

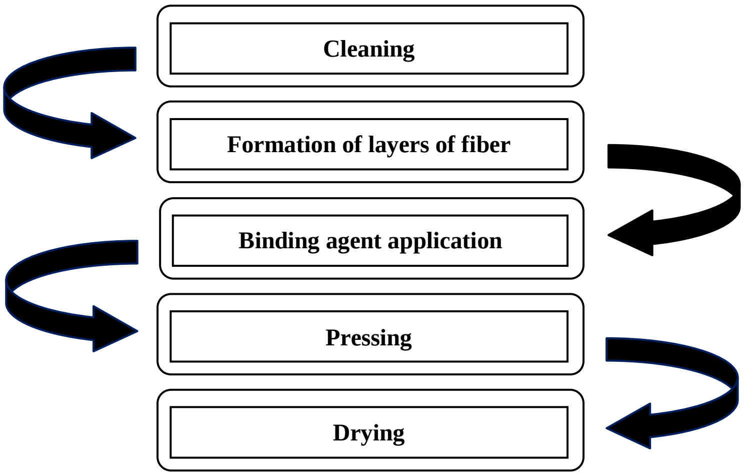

Figure 1 – Cycle of processes developed to manufacture the proposed panels.

The cleaning stage seeks to minimize the amount of impurities in the fibers. In the next stage, layers of fibers are formed in order aggregate them at the end of the pressing process. A binding agent based on acrylate and water, obtained commercially, is then applied over the fiber layers until they have enough adherence to originate the panels by layers superposition. The fiber layers are now overlapped, already with the binding agent applied, and then pressed to promote final aggregation of the panel. The pressing time and pressure are different for each fiber due to the differences in their porosity, density and geometry. The drying process is made exposing the panels to sun and wind. For the manufacture of panels, their mass was used as a control parameter , i.e., all manufactured panels had approximately the same mass (about 1 kg), also keeping equal surface areas, which in this case are 0.3 m^2, which is the required surface area that a sample must present to be tested on the scale model reverberant chamber available. The identification of the panels is made of the following manner, the number 1 refers to the panel of açaí fiber, the number 2 corresponds to the panel of palm fiber, the number 3 refers to the panel of coconut fiber, and the number 4 is associated with the panel of sisal fiber (see figure 2)

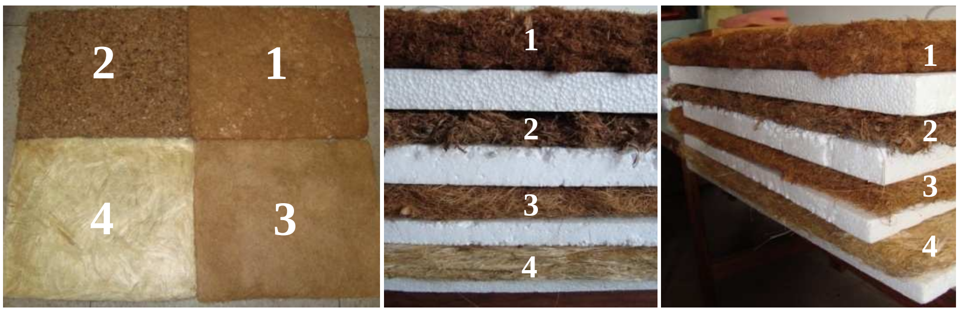

Figure 2 – Panels of açaí (1), palm (2), coconut (3) and sisal (4) fibers.

3.4. Acoustic characterization of the panels

After the manufacturing process, the fiber panels as well as the acoustic conventional materials were tested on a scale model reverberant chamber, in order to have their sound absorption coefficients measured, using a frequency analyzer and the noise interruption method, aiming a performance comparison between results. The procedures adopted to perform the acoustic characterization are provided by the ISO 354/1999. The conventional materials in question are acoustic panels of the type SONEXflexonic of 20 mm and 35 mm of thickness from manufacturer Illbruck. Those materials were selected because they present similar thickness to the panels, making the comparison more appropriate.

The experiments were conducted at the Laboratory of Acoustics of the Acoustics and Vibration Group (GVA) of the Federal University of Pará (UFPA). The scale model reverberant chamber used was qualified according to requirements of the ISO 354/1999. Its volume is of 0.96 m^3 approximately; its structure is basically made of plywood and is assembled over vibration isolators, including sound diffusers made of polyvynil chloride (PVC). The sound source is fixed in one of the corners of the chamber (see Figure 3.b), maximizing the probability of exciting all the chamber acoustic modes.

Because the panels are handmade, they have not shown a uniform thickness, even in the case of panels made of the same type of fiber.

The quantification of the sound absorption coefficient of a given material consists of measuring the reverberation time of a room containing a sample of the material, and comparing the results with those for the empty room.

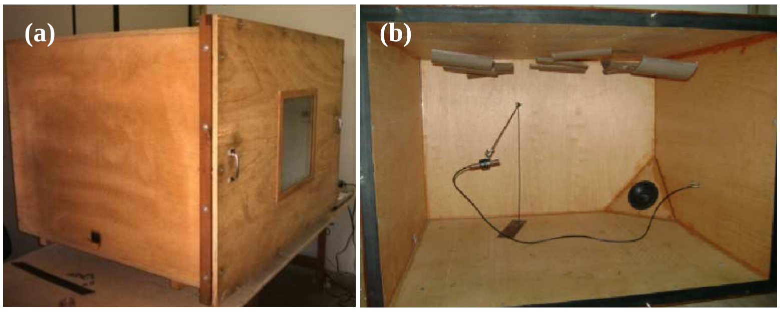

Figure 3 – Scale Model Reverberant Chamber of the Laboratory of Acoustics of UFPA (a) and detail of its interior (b).

After determination of the reverberation time of the chamber with and without a given sample in its interior, the sample sound absorption coefficient, as a function of frequency, can be calculated, according to ISO 354/1999, from Eq. 1.

$$\mathrm{A_a} = \frac{55{,}3\mathrm{V}}{\mathrm{c}}\left(\frac{1}{\overline{\mathrm{T}}_2} - \frac{1}{\overline{\mathrm{T}}_1}\right) \quad \text{(square meter)} \tag{1}$$

Where $\overline{\mathrm{T}}_2$ is the average reverberation time of the chamber with the sample in its interior, $\overline{\mathrm{T}}_1$ is the average reverberation time of the empty chamber, V is the volume of the chamber, and *c* is the speed of sound in the environment.

Thus, the material sound absorption coefficient can be obtained through the following equation:

$$\alpha_\mathrm{a} = \frac{\mathrm{A_a}}{\mathrm{S}} \tag{2}$$

Where *S* is the surface area of the sample.

3.5. Results

So that the results may have reliability, a series of requirements and standardized procedures must be followed. In the case of the ISO 354/1999, one of the requirements is that the difference between the background noise level (BNL) and sound pressure level (SPL) emitted by the source is at least 15 dB for each one-third octave band. The figure below shows that difference was respected (see Figure 4).

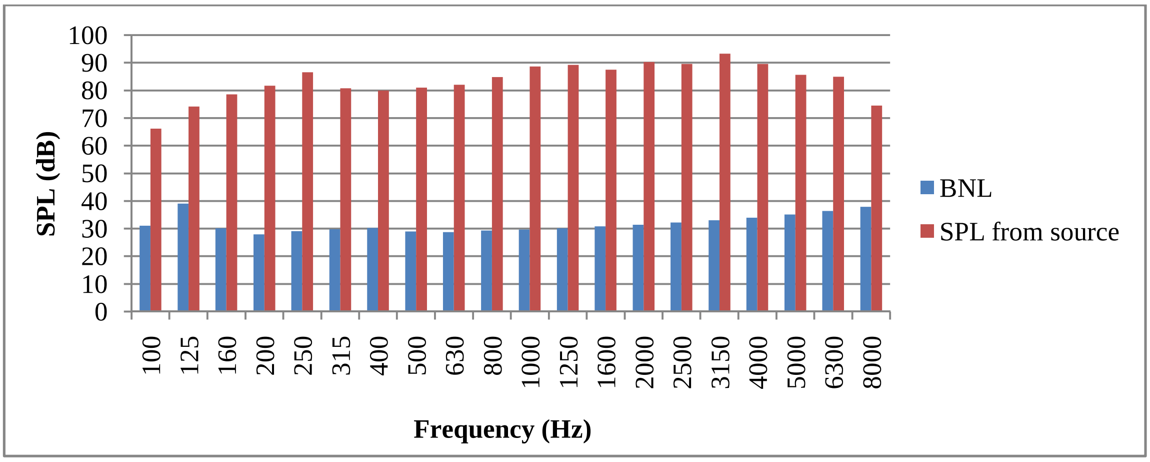

Figure 4 – Comparison between the SPL emitted by the source and the BNL.

The results obtained for the sound absorption coefficients of the tested materials are shown below (see Figure 5).

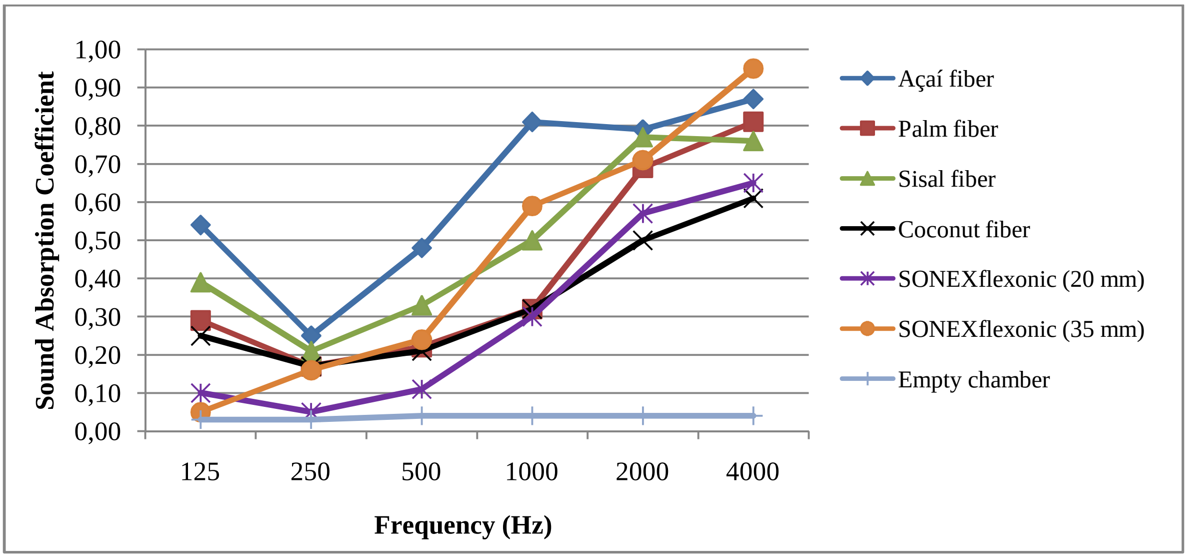

Figure 5 – Comparison between sound absorption coefficients of tested materials.

Analyzing the graph of Fig. 5, it can be noted that the acoustic performance of the panels was very satisfactory since surpassed that for one of the tested conventional materials (SONEXflexonic 20 mm) in most part of the frequency range, whereas, in relation to the material SONEXflexonic 35 mm, only the panels of açaí and sisal fibers presented superior performance, being considered then as the panels with best acoustical performance among the tested materials. It is important to emphasize that none of the panels of fibers had thickness exceeding 30 mm, since comparisons were made with conventional materials of higher thickness (SONEXflexonic 35 mm). Stressing the fact that the tests were conducted on scale model reverberant chamber, the results are more representative, according to Fig. 5, after 500 Hz.

3.6. Conclusions

The present work investigated the acoustical performance of newly developed natural fiber panels using the available apparatus of the Laboratory of Acoustics of UFPA, which consists of a scale model chamber (1:6), commonly used for academic purposes by the Acoustics and Vibration Group of the referred university.

As expected, the results obtained through the scale model reverberant chamber are influenced by the degree of diffusion of its sound field, which is directly related to chamber construction material characteristics, i.e., the more rigid the internal coating material of the chamber is, the more diffuse its sound field will be, in addition to dimensional factors, since the small size of the chamber does not contribute for the sound diffusion on its interior. It is important to notice that the scaling factor of the chamber is not used here to shift the interval of measuring frequencies. Rather, the chamber is used as a valid reverberant room.

When acoustic performance comparisons of materials are made, even keeping under control parameters on the test environment such as temperature and relative humidity, for example, the results for the same sample may present differences; this is due to variations of the involved parameters in the formulations inherent to the testing statistical method used on reverberation chambers. However, the analyses made in this study sought to establish a qualitative comparison between the investigated materials, testing them in the same environment, and under the same conditions, i.e., an hypothesis was made such that, the material which presents the best performance on the scaled chamber used, will also produce the best performance on a full scale chamber.

Alternative materials such as panels manufactured from vegetable fibers can be used as acoustic materials, as they have shown good acoustic performance, presenting, in some cases, superior performance when compared to that of conventional materials, commonly used for the purpose of noise control indoors. The future use of these newly developed materials has, therefore, the potential of reducing projects' costs, environmental impact, and even generating employment and income to local workers, involved in the manufacturing process of such panels.

4. ACKNOWLEDGEMENTS

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