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EXPERIMENTAL STUDY FOR ACOUSTIC CORRECTION OF A SCHOOL CLASSROOM USING THE ALFA PANEL

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Abstract- Research on sound-absorbing materials made of natural bio fibers is an emerging area in sustainable materials because of its positive impact on the environment. Producing more eco-friendly materials, replacing synthetic fibers with natural and less expensive materials, is the main objective supporting these studies. This study aims to determine the acoustic effect of Alfa panel on classrooms. The acoustic performance of Alfa was calculated based on the sound absorption coefficient trough reverberation time measurements on Small-sized reverberation chamber built as part of this application. Furthermore, conducted measurement reverberation time measurements in classrooms of the Bougadi El Djamaii high school in Oum El Bouaghi City, Algeria, to assess the problem and recommend solutions. Alfa material is deemed to be an ideal material to create efficient acoustic Panelsthat can improve the intelligibility of speech. Results showed that Alfa panels give similar, sometimes better, results than panels formed from mineral wool of the same thickness.

Keywords: Sound Absorption, Acoustical Performance, Alfa Panel, Eco-Materials.

1. INTRODUCTION

Eco-materials have the potential to be used as high-performance noise absorbers and isolators in number applications. These applications include transport, architecture, industry, and construction [1]. The effects of a sound environment in speech comprehension become important for children in classes where it is important to hear and understand the details of the voice. Presently, acoustic panels are able to absorb the sound energy available in the market of acoustic treatments made from synthetic materials such as glass wool and stone wool. These synthetic materials not only harm human health, but can also cause pollution and global warming [2]. The introduction of eco-materials is vital for environmental reasons and their use to absorb acoustic waves in rooms has recently received increasing attention [3]. Furthermore, natural fibers such as Alfa are good candidates to replace expensive synthetic fibers that are not respectful of the environment [4].

A fair amount of research has been carried out to define the acoustic properties of new natural porous materials. P.A. Chabriac et al. (2016) [5] defined the acoustic characteristics of five widely available plant particles (hemp, bark, sunflower pith, flax straw, and rapeseed straw). The results show that these materials can be used for sound absorption and that their sound absorption coefficients are truly interesting. Their absorption for a given thickness can be equivalent to those of typical commercial sound absorbers like glass. In this same context, green acoustic panels made from coconut fibers have been characterized with an impedance tube to measure absorption coefficients with a vision to use them as acoustic absorbers in rooms [6]. Another study developed by the same method (Kundt tube) defined the sound absorption performance of empty oil palm fruit. Research results have shown that the absorption coefficient of this material can reach up to 0.9 averaging above 1 kHz [7].

All of these studies explore the opportunity to research other materials from natural fibers to make a "green" acoustic panel as a timely solution to current hazardous materials. Natural fibers, such as wood, hemp, and coconut fibers, have the potential to transform expensive synthetic fibers into sound-absorbing panels. It is in this context that our work is incorporated by proposing Alfa, which is a local natural and very abundant material in the Algerian Sahara and presents interesting characteristics from the aspect of sound absorption. Therefore, the development of Alfa-based sound absorption in Algeria and other North African countries where this material can be found in abundance is very promising. Porous absorbers are the most widely used and widely used sound absorbers. Excellent sound absorption is evident when it allows sound waves to perforate absorbers where sound disperses against heat. The amount of sound that enters the wings depends on the length of the sound and the intensity of the ventilation. The intensity of a sound receptor is usually defined by the frequency of the sound absorbing [8].

In this context, we offer Alfa as an absorbent material that can have good acoustic performance. In Algeria, Alfa has been the material of choice for nomads since prehistoric times. It was used in making kitchen utensils because of its light weight which allowed easy transportation. In this sense, we propose it as an acoustic material since the manufacture of panels from this material is easily achievable [9].

This work is being researched to investigate how the panels designed from Alpha affect the visual noise in the children's classroom. In addition, bad acoustics in the classroom are not limited to traffic noise and noise from nearby school areas, but also from reverberation is that leads to a buildup of the sound intensity in the room [10, 11, 12]. The absorption of panels made from Al Famake the reverberation time shorter which improve clarity of the acoustic signal and thereby better intelligibility [13].

2. MATERIALS USED

2.1. Alfa panel

The objective of this research is to measure the sound absorption properties of the samples prepared for this study. The sample made of a local material (Alfa) that we have chosen is an alternative to the very expensive imported acoustic panels currently used [14]. The Alfa, L. Stipa Tenacissima, is one of the dominant perennial grasses, typical of the Maghreb steppe ranges [15]. It is a very robust, stiff, dry, very persistent species. It appears in dense tufts, with long and leathery leaves, the inflorescence is long (30 cm) and very dense. The Alfa has underground roots which are very important for regeneration and an aerial portion which is up to 1 m high. However, the real development of Alfa as an industrial plant of wide use dates from the end of the 19th century when, the Routledge process, Scottish paper mills were able to use it as a raw material for the manufacture of pulp [16]. The land of choice for Alfa is North Africa, particularly the highlands of Algeria and Morocco. The territorial distribution is estimated at: - Algeria: 4000000 ha - Morocco: 3186000 ha - Tunisia: 600000 ha. - Libya: 350000 ha. - Spain: 300000 ha [17] (Figure 1).

Figure 1. Material Alfa [17]

An expert was invited to prepare for our use the model of the Alfa in the traditional way. The fibers were washed and dried before use. It was made from a full tube of several Alfa fibers that revolve around a center away from it. This gives us a round wavy shape with a 40 cm of diameter and 08 mm thickness (Figure 2).

2.2. Acoustic Model (Reverberation Chamber)

In order to define the acoustic characteristics of the Alfa material, we have developed a reduced-size model. It is a closed glass volume (10 mm thickness) supported by a metal frame (exoskeleton) in flat iron 30×4 mm², the simulated model is obtained through an envelope completely covered with glass (Figure 3) (Table 1), with [2.00×0.80] m² at the base, 1.2 m high on one side and 0.8 m on the other.

The chamber has been fitted with a removable glass panel to its original condition which can be replaced with other panels that can be considered for future testing. The 8 mm holes are drilled and reserved for the speaker cables at the back of the room. The receivers are in the middle of the room, and others in the middle reserved for the microphone cables (Figure 4).

Figure 2. Model of the Alfa

Figure 3. Acoustic glass model

Table 1. Characteristic of the model and test samples

Glass surface of the model	Alfa panel density	Alfa panel thickness	Alfa panel surface	Glass surface of the model
1.60 m^3	99.4 Kg/m^3	8 mm	0.125 m^2	8.8 m^2

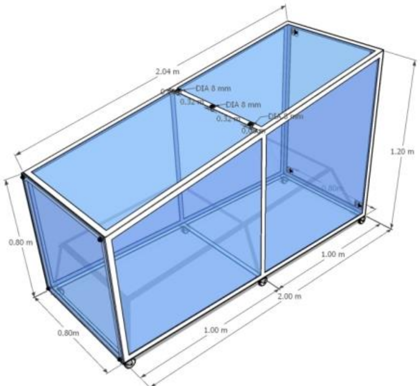

Figure 4. Dimensions of the acoustic model

3. METHOD OF WORKING

The reverberation time measurements were made using an Emission Source to simulate an impulsive sound (balloon) (Figure 5.a) placed in the corner of the model and directed towards the opposite corner in diagonal. An explosion will produce a pulsating sound of a high level of intensity inside the reverberation chamber. Reverberation ensues, which results in a decrease in sound level over time. The speed of the decrease in this sound level will be proportional to the absorption of the internal walls of the chamber, which will tell us about the absorption coefficient of the chamber. This decrease in sound level will then be recorded by the omnidirectional microphone of VoIP type 6 mm of sensitivity -40 dB with a frequency band (100-12000 Hz) (Figure 5.b), The microphone is placed at a height of 0.06 m equivalent to a height of 1.20 on the real scale, it can be noted that these dimensions respect the scale of the model at a ratio of 1 / 20th. This microphone was connected to a PC running Windows 7 for a recording of the decay signal (Figure 5.c). This signal will then be processed by the Spectra RTA software for the measurement of the reverberation time and the deduction of the absorption of the chamber.

a b c

Figure 5. a. balloon, b. Omnidirectional microphone, c. PC for the acquisition and recording of the pulse signal

Once the equipment installed in the room, the microphone is placed in the actual listening position. When the SPECTRA RTA software is launched for RT60 analysis, the balloon is exploded giving a brief and powerful sound pulse which will excite all the walls. The measurement system (software) makes it possible to recover the signal at the given point in the room where the microphone was placed. The recording takes place over a period of 3 to 5 seconds following absorption of the chamber. The RT60 is then calculated over several octave band frequency bands. We then obtain decay curves of the sound level as shown in the figure below. The measurement of the RT60 is made from the duration of the decrease in the sound level of the signal between the initial level corresponding to the peak of the recorded signal and the attenuation of the sound level of the signal by 60 dB.

The recording took five seconds and the explosion occurred approximately 2 seconds after the Spectra RTA software started recording. The level of the explosion above the background noise of the room is about 50 dB and the decay is almost linear with time. To measure the TR60 time over a period of 60 seconds, an extrapolation of the curve by 20 dB more is necessary as shown in Figure 7.

The extrapolation was necessary because the explosion is not powerful enough to have the level 60 dB level above the background noise of the room, that is to say 1000 times the background noise of the room knowing that:

Sound level = 20 log(explosion signal) / (background noise)

Note that the reverberation time Tr60 is approximately 1.60 seconds after extrapolating the decay curve.

Generally, for large rooms where it is very difficult to obtain a very high sound level, the reverberation times are measured with TR30 (that is to say 30 seconds after the spike) then are multiplied by two to obtain the RT60. For information, we can also have the recordings in the octave of 500 Hz and 2000 Hz.

Knowing that the reverberation time is linked to the absorption of the material and therefore the absorption coefficient, the expression of the reverberation time is given by Equation (1) [13].

$$t_1 = \frac{0.16 \times V}{A} \tag{1}$$

where, t represents the reverberation time, V the volume of the room and A is the absorption of the material which can also be expressed by Equation (2) [13].

$$A = \alpha \times S \tag{2}$$

where, α is the absorption of the material, and S is the surface.

This method can be used if we add another material whose absorption coefficient is δA and absorptionα, in the room with absorption A, Sabine's formula becomes [13]:

$$t_1 = \frac{0.16 \times V}{A + \delta A} \tag{3}$$

t_1: reverberation time of the room

t_2: reverberation time of the room with extra absorption

The combination of the two formulas mentioned above gives extra absorption [20];

$$\delta A = 0.16\left[\frac{1}{t_2} + \frac{1}{t_1}\right] \tag{4}$$

Finally, the absorption α of the sample is calculated by dividing the absorption α by the area of the sample S [20]

$$\alpha = \frac{\delta A}{S} \tag{5}$$

4. RESULTS AND INTERPRETATION OF MEASUREMENTS

The following will give the preliminary results obtained in this study.

4.1. Empty Model Without Coating

The results obtained in the case of the empty model (Figure 6) show that the average reverberation time varies between 0.77 seconds for the frequency 315 Hz and 0.7 seconds for the frequency 8000 Hz, while the absorption coefficient α varies between 0.004 at 315 Hz and 0.007 at 8000 Hz.

This absorption coefficient is related to the glass used for the assembly of the model, very close to the coefficient found in the literature [18], which demonstrates the validity of the experimental method. It can be noted that the measurement was carried out twice in order to take the average of the two results of the reverberation time. Indeed, in acoustic measurements, it is advised to make measurements of the reverberation time in five places of the room, the ends (the four corners of the room plus the center). In our case, the distances are not too substantial so we are able to consider that the sound distribution is almost uniform. The energy dissipated in the low frequencies is low; therefore, the response is almost random.

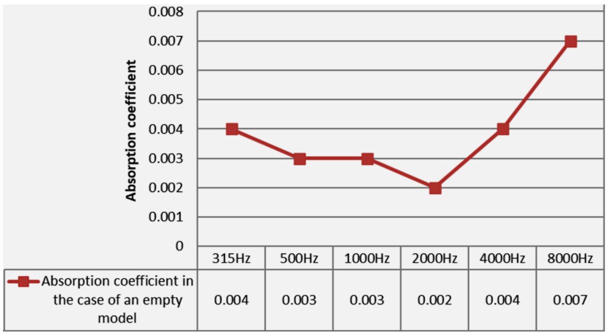

Figure 6. Recording of the reverberation time at the frequency 1000 Hz

4.2. Model Plus Alfa Acoustic Panel

The results show that the absorption coefficient of Alfa is very important, especially in the middle and high frequency range, reaching its maximum value of 0.83 at a frequency of 3000 Hz (Figure 10). The best sound absorption performance of the Alfa is in the medium and high frequency ranges. This is due to its surface and its wavy structure (Figure 7). The incident wave hits the surface of the panel, part of the energy will be reflected by the panel because of the difference in acoustic impedance between the air and the material then another part of the energy will be absorbed by the material in the form of heat dissipation and finally some energy will be transmitted to the other side of the sample. The energy dissipation which interests us in the material depends on the porosity, its density, as well as the distance of the panel from the wall.

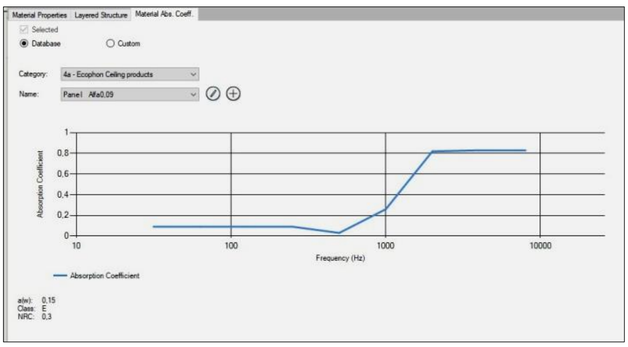

Figure 7. Absorption coefficient in the case of the empty model

5. CASE STUDY

The Bougadi El Djamaii high school with 800 spaces is a school located in the south-east of the city of Ain Fakroun, in the region of Oum el Bouaghi in Algeria. It includes (27 classrooms, 40 laboratories, libraries, cafeterias, gymnasiums, and administrative spaces). For this study, we chose a classroom on the third floor, with an area of 42.18 m² (5.70×7.40) m and a ceiling height of 2.98 m (Figure 8).

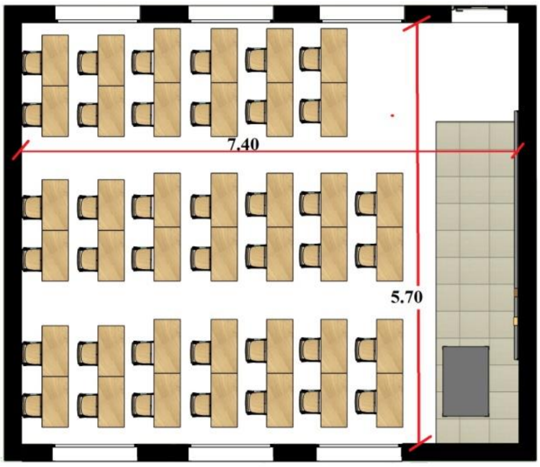

Figure 8. Plan of the classroom

5.1. Estimated Reverberation Time

The reverberation time TR is the most important acoustic condition in any conference room [19]. The best design is the one that gives the ears a seamless reception of the sounds of speech. Using software from SKETCHUP, a 3D model was created. This model contains all the details of the various architecture and finishing materials. Includes elevated sound source space located in the middle of the stage in the platform. The model was analyzed audio using the Olive Tree Lab SUITE software to calculate their use time. In simulation, the suction coefficients "a" of the different faces of the models selected in the table provided by Olive Tree Lab SUITE (Figure 9).

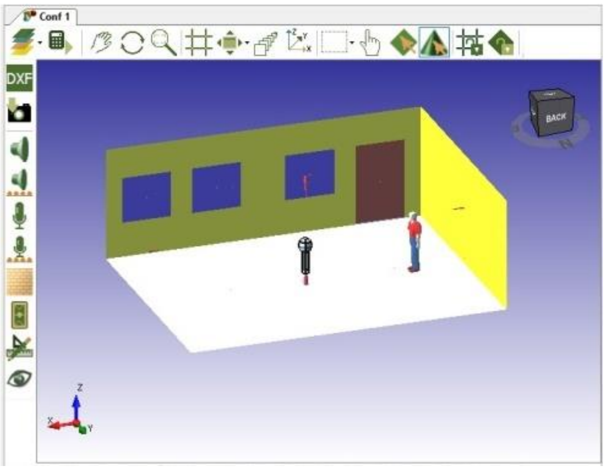

Figure 9. Digital classroom model introduced on Olive Tree Lab SUITE software

5.2. Results and Interpretation

The results show that the reverberation time TR60 of the room is very high compared to the optimal value of the reverberation time which must be within the margin of (0.6-1.2) seconds [20] (Figure 10). Reverberation directly affects speech intelligibility and reduces comprehension, which significantly decreases the acoustic quality of the room.

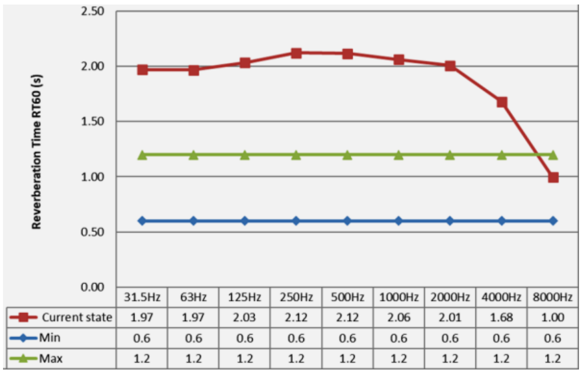

Figure 10. Values of TR60 compared to optimal TR60

6. Corrections Proposed for the Classroom

For better acoustic quality in the classroom, we opt to insert a series of three Alfa panels (0.6×7.50) and 08 mm thick on the ceiling (Figure 11).

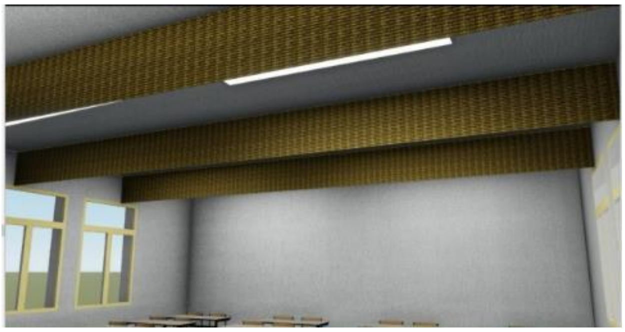

Figure 11. Alfa panels inserted in the classroom

6.1. Estimated Reverberation Time of the Classroom after Modification

We entered the acoustic characteristics of the Alfa's panels into the Olive Tree Lab Suite software material database to assess the impact on the acoustic performance of the classroom (Figure 12).

6.2. Results and Interpretation

The application of Alfa panels with its high sound absorption coefficient to the ceiling of the room has significantly contributed to reduce the reverberation time values, for the frequency 1000 Hz the TR60 went from 2.06 to 1.01. The simulation results show that the correction largely modified the acoustic environment of the classroom, The decrease in reverberation time represents up to -49% for (125 Hz), -48% for (250 Hz), -44% for (500 Hz) -51% for (1000 Hz) and -49% for (4000 Hz). By comparing these results with the optimal value of TR60 for the frequency of 500 Hz we notice that the reverberation time after correction became 1.18 s below the optimal value which is 1.20 s. This confirms the effectiveness of the proposed corrections with Alfa panels.

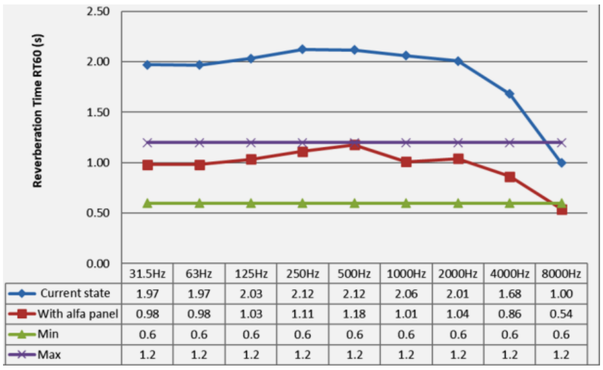

Figure 12. Room TR60 values after insertion of Alfa panels compared to optimal TR60

7. CONCLUSION

In the first part of the research, we were able to reduce the absorption coefficient of the Alfa panel made up essentially of ecological and durable material. Alfa is one of the synthetic fibers with several specific advantages, including its abundance, its renewal capacity, its recyclability and its high specific resistance. The results recorded in the second part of the research (through simulation) showed that the modifications proposed for the acoustic corrections of the classroom were greatly significant due to the setting up of the suspended panels. Alfa showed a noticeable improvement in the acoustic quality of the classroom

NOMENCLATURES

A	Equivalent absorption area [m^2]
V	Volume [m^3]
TR	Reverberation time [s]
α	Sound absorption coefficient

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BIOGRAPHIES

Dalal Farid was born in Constantine, Algeria on April 20, 1984. She received the Dipl. Ing in 2006 and the magisterium diploma was on the preservation of architectural heritage at the University of Constantine 3, Algeria, in 2014. She is a doctoral student and responsible for research at the laboratory of bioclimatic architecture & environment, Constantine 3 University, Algeria from 2014. She is a lecturer in critical history of architecture and project theory at Department of Architecture, University of Larbi Ben Mhidi Oum El Bouaghi, Algeria, from 2015. Her research focuses on the acoustic correction of conference rooms and absorbent ecological materials.

Samira Debache Benzagouta graduated with bachelor of Architecture from University of Constantine 3, Algeria. She Received her Ph.D. from University of Constantine Algeria in 2004 and her investigation involved exploring the problems of noise in high rise buildings. She holds an M.Phil. degree in architecture from the University of Leeds where she investigated mass housing production and processes with a focus on Algeria. She is a Professor, Doctor (Ph.D.), research laboratory ABE, researcher and lecturer at Faculty of Architecture & Town Planning, University of Constantine 3, Algeria. Her recent interest covers several topics underlying the area of heritage conservation.

Youcef Remram earned his M.Phil. of physics from Bath University, UK, in 1987, and his Ph.D. in electronic instrumentation from USTHB, Algeria in 2010. He is currently Professor of electronic instrumentation at University of Science and Technology Houari Boumediene (USTHB), Algiers. His research interests lie in the area of ultrasound in bone, acoustics and electronic instrumentation. In recent years, he conducted a National Research Project (PNR) with his team in climate control in green houses where they have been awarded the best national project team. He developed many projects room acoustics especially in Mosques.