ACOUSTIC CORRECTION USING GREEN MATERIAL IN CLASSROOMS LOCATED IN HISTORICAL BUILDINGS

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The acoustic correction inside classrooms located in historical buildings using absorbent panels is difficult for aesthetic reasons. Furthermore, architectural restrictions are often imposed to preserve the historical heritage. The acoustic measurements inside the classrooms show high reverberation time values, which imply an adverse environment for speech reception. In this paper the reverberation time in classrooms located in historical buildings was reduced by installing removable sound absorbent panels. The panels were made with "green material". The absorbent material was obtained by crushing giant reeds of sweet water, a plant which grows quickly in wetlands. The crushed material was then put in jute sachets, installed in the wooden frames and covered with different colours jute cloth for aesthetics. Acoustic measurements were made in the classrooms with smooth plaster walls, without students. A virtual model of the classroom was drawn with 3D CAD. The surface area covered with green material absorbent panels was evaluated by the software Odeon. After the installation of the absorbent panels, comparisons between the virtual classroom acoustic properties and the real classroom acoustic properties were made to validate the effect of the green absorption panels.

INTRODUCTION

Due to aesthetic and historic reasons, it is difficult to install sound absorbent panels for acoustic correction in classrooms located in historical buildings. Usually the dimensions of such classrooms (volume and area) are large so the reverberation time is high (over 2 seconds) [1]. Furthermore, classrooms located in historical buildings are not regular in shape and the ceilings are not plane. To improve the acoustic characteristics of classrooms, sound absorbing materials are usually suspended on the walls; however in historical buildings it is not possible to use fixed structures [2].

Absorbent panels are generally made with traditional sound absorbent materials such as glass wool, rock wool, polyester or polyurethane foam. In this paper a sustainable "green material" was used as the sound absorbent material. This has the advantage that at the end of its useful life, it can be disposed of without difficulty and without damage to the environment. In addition, green materials store carbon dioxide during their growth.

In order to evaluate the classroom surface area to be covered with the green material absorbent panels, this study used the architectural acoustic Odeon software in conjunction with a classroom virtual model. Classrooms of the Faculty of Architecture of the Second University of Naples (SUN) were selected for the study. The Faculty of Architecture is located in an ancient building in the city of Aversa near Caserta (Italy). The building was built in the 10th century as a Benedictine monastery. It was then expanded in the 15th century and later converted into a school and finally into a University in 1990. Figure 1 shows the cloister on two levels with arches and columns. The classrooms were irregularly shaped, with vaulted ceilings and smooth plaster walls. The acoustic parameters measured in each classroom were: Reverberation Time (T_{30}), Early Decay Time (EDT), Definition (D_{50}) and the Speech Transmission Index (STI) [3].

Figure 1. The cloister on two levels with arches and columns

ACOUSTIC MEASUREMENTS

The acoustic measurements were carried out in seven classrooms, using an omnidirectional spherical source fed with a Maximum Length Sequence (MLS) signal. The impulse responses were detected with a measurement microphone GRAS 40 AR endowed with the preamplifier 01 dB PRE 12 H connected with a laptop PC through the interface 01 dB Symphonie. The sound source was placed in each classroom at the teacher's position (height 1.6 m). The microphones measurements were set in different points at a typical ear height of 1.2 m, to obtain average values of the classroom acoustic parameters. The acoustic parameters were measured according to ISO 3382 [4]. Figure 2 shows the omnidirectional sound source in the classroom at the teacher's position, and the measurement microphone between the tables. During the acoustic measurements the background noise was lower than 50 dBA, the classrooms were empty without students and the furniture consisted of hard chairs and rows of hard tables. The classroom had smooth walls, wooden doors and glass windows [5,6]. Table 1 shows the average geometrical dimensions for the seven classrooms. For these same classrooms, Table 2 shows the STI average values measured, Table 3 shows T30 average values measured and Table 4 shows D50 average values measured. All the acoustic parameters considered show that in the classrooms the quality of speech reception is poor.

CASE STUDY

Classroom T4, a room with smooth plaster walls, was chosen as the case study. This plan is 9.0 m long and 5.0 m large. The average height is about 5.0 m and the volume is 240 m^3 (Figure 3). In the classroom there are thirty hard chairs and six rows of hard tables; the students' seating area is 5.30 m × 2.50 m. When the classroom is empty (without students), the measured values of STI, T_{30} and D_{50} are respectively reported in Tables 2, 3 and 4. The acoustic parameters measured indicate that in this classroom, the speech reception was not good. Furthermore tests administered to students have confirmed that the speech intelligibility was poor.

Figure 2. Acoustic measurements in the classroom

Table 1. Classrooms average dimensions

Classroom	T4	T5	P3	P4	S2	S3	T1
Volume, m^3	240	2517	416	1200	626	1850	202
Average height, m	5.0	12.1	5.4	5.5	4.6	7.2	4.5
Base area, m^2	50	208	77	217	136	257	45

Table 2. STI average values measured

Classroom	T4	T5	P3	P4	S2	S3	T1
STI, measured	0.34	0.38	0.48	0.47	0.47	0.46	0.47

Table 3. T_{30} (s) average values measured

Frequency, Hz	125	250	500	1k	2k	4k
T4	3.43	2.44	2.04	1.76	1.70	1.41
T5	4.67	5.41	4.23	4.0	3.15	2.14
P3	2.83	2.67	2.18	2.24	1.81	1.56
P4	3.22	2.88	2.77	2.44	2.22	1.81
S2	2.79	2.78	2.69	2.63	2.25	1.74
S3	3.04	2.73	2.72	2.66	2.24	2.0
T1	3.49	3.43	2.77	2.37	2.21	2.01

Table 4. D_{50} average values measured

Frequency, Hz	125	250	500	1k	2k	4k
T4	0.23	0.16	0.22	0.30	0.27	0.33
T5	0.22	0.16	0.15	0.23	0.29 5	0.50
P3	0.23	0.30	0.30	0.31	0.34	0.40
P4	0.23	0.27	0.27	0.31	0.38	0.44
S2	0.28	0.30	0.23	0.26	0.33	0.41
S3	0.30	0.34	0.31	0.27	0.25	0.34
T1	0.22	0.22	0.28	0.32	0.30	0.35

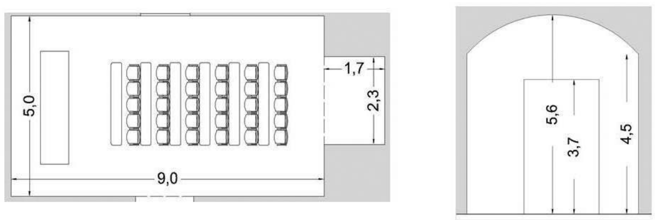

Figure 3. Classroom plan and section dimensions (in metres)

ACOUSTIC PROPERTIES OF THE MATERIAL

For the classroom acoustic correction, sustainable materials termed green materials were chosen [7-11]. These materials are generally employed for energy saving purposes (heat insulating materials). Recently they have also been applied in architectural acoustics to replace the traditional sound absorbent materials (glass wool, rock wool, polyester, polyurethane foam, etc). Sustainable materials have the advantage that they can be disposed of without difficulty and without damage the environment at the end of their useful life. The sustainable material used in this study is a giant reed of sweet water (arundo donax). It is a material commonly available in country sides near rivers, lakes and wetlands. This plant grows very quickly, usually reaching 6 m in height and a diameter of 2-3 cm. The giant reeds were cut, dried and then crushed. They were then shredded into flakes of small size, with average dimensions of 40 mm length, 10 mm width and 3.0 mm thickness (Figure 4). The loose grains obtained were placed in sample sacks made of jute which were tested by the measurement system.

To assess the material acoustic properties, the absorption coefficient at normal incidence was measured with a Kundt's tube, in accordance with ISO 10534-2: 1998 [12]. The Kundt's tube has an inner diameter of 100 mm, length of 560 mm. With distance between the two measuring microphones of 50 mm the absorption coefficient measurement is accurate in the range frequency of 200 Hz – 2 kHz. Using the distance between the two measuring microphones of 100 mm, the absorption coefficient measurement is accurate in the frequency range of 100 Hz – 1 kHz.

Figure 5 presents the average value of the absorption coefficient measured at normal incidence in the frequency range 125 Hz – 2 kHz with Kundt's tube [13]. This average value is obtained from measurements with four different specimens (thickness 40 mm). The material has a good value of the absorption coefficient at the medium frequencies. The loose materials were inserted in the tube measurement and stopped with a net metal, so the Kundt's tube was in a horizontal position. The measured absorption coefficient values are similar to those of limestone chips with the same thickness [14]. The loose material was then inserted in jute sacks in order to obtain a layer of sound absorbent porous material and mounted in wooden frames covered with a jute burlap (Figure 6). Since the jute burlap has a large mesh and low air resistance, it can be considered as an acoustically transparent material.

Figure 4. Loose grains average dimensions

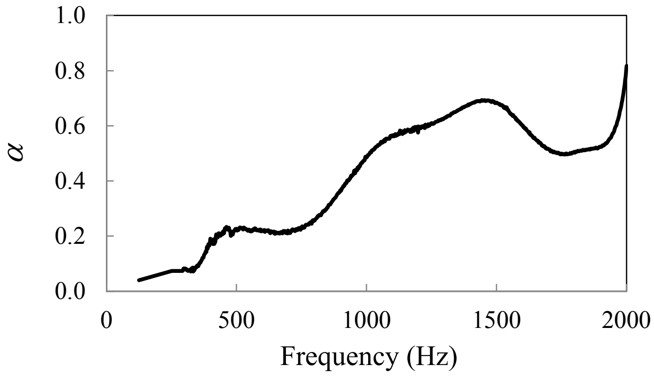

Figure 5. Average values for the absorption coefficient α measured at normal incidence in the frequency range of 125 Hz – 2 kHz

ODEON VIRTUAL MODEL

A software used for architectural acoustics, Odeon, was used to evaluate the classroom surface area to be covered with absorbent material in order to obtain an acoustic correction. The Odeon software imports a virtual model drawn by 3D CAD [15]. Figure 7 shows the 3D virtual classroom model with the virtual omnidirectional sound source in the teacher position, and the virtual receivers in the student positions. Figure 8 shows the classroom render with the absorbent panels insertion. The Odeon virtual model had 88 corners, 35 surfaces in the room and a total surface area of 254 m^2.

The first operation is the acoustic model calibration which consists of setting the absorbent coefficient values for all virtual model surfaces and setting the scattering coefficients. The scattering coefficient s does not depend on frequency, but on the surface geometrical properties; so the desks and chairs were simulated as flat planes, with a scattering coefficient s=0.5 for the unoccupied condition. The calibration operation is stopped when at each octave band frequencies (125 Hz – 4 kHz) the value of reverberation time (T_{30}) calculated is equal to reverberation time (T_{30}) measured.

Figures 9, 10 and 11 respectively show the comparison between the acoustic parameters values T_{30}, EDT and D_{50} both measured and calculated using the Odeon software, when the classroom with smooth walls is empty (without students). After the calibration operation, the acoustic absorbent panels with surface area 11 m^2 with the values of absorbent coefficient given in Figure 5 were inserted in the virtual model. The values of the absorbent coefficient at 4.0 kHz were obtained by extrapolating the measured values. In this configuration, the calculated value for speech transmission index (STI) is 0.45. For the EDT, the difference between measured and calculated values is negligible, while for the STI and the D_{50}, the calculated values are higher than the measured values.

Figure 6. Sound absorbent panels

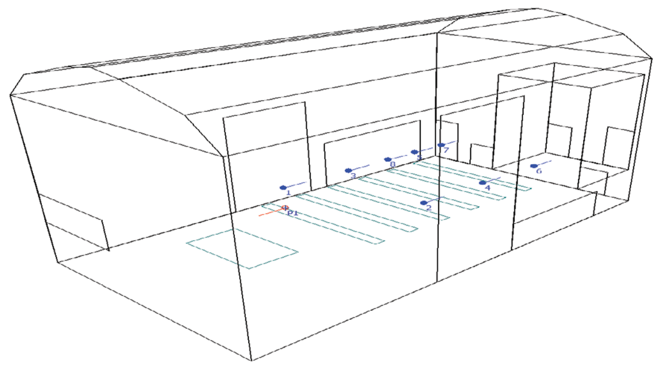

Figure 7. 3D virtual model by Odeon, with the sound source and receiver position

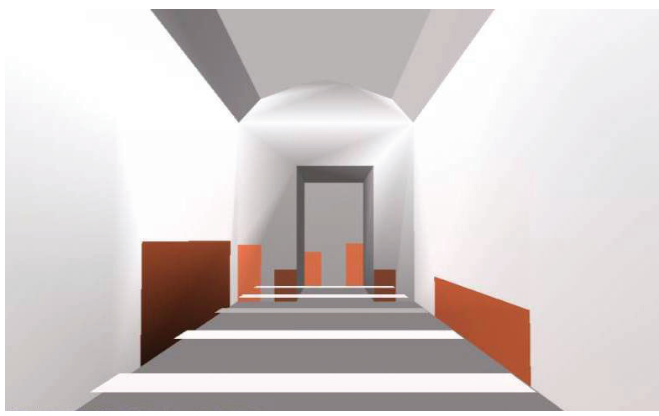

Figure 8. Render of 3D virtual model by Odeon with the absorbent panels insertion on the walls

FULL SCALE ACOUSTIC MEASUREMENTS

Figure 12 shows the green material absorbent panels located in the classroom covering an area of 11 m^2. The absorbent panels are installed in a temporary manner due to aesthetical and historical reasons, and in accordance to Superintendence of historical heritage architectural restriction. During the acoustic measurements, the omnidirectional sound source and the receivers were put in the same initial positions (teacher and students positions). The comparisons between measured and calculated values are presented in Figures 13-15 for reverberation time (T_{30}), early decay time (EDT) and definition (D_{50}), respectively. In this configuration, the calculated value STI = 0.56, while the measured STI is 0.55. The difference between measured and calculated values for the T_{30} and EDT parameters is negligible, while for the STI and D_{50} the calculated values are higher than the measured values.

CONCLUSIONS

This paper demonstrates the possibility to obtain a good acoustic correction inside classrooms using a green material corresponding to the giant reeds, properly shredded and re-assembled into panels. The green material is inserted in jute bags where the jute has a large mesh and a low air resistance and as such is an acoustically transparent material. Using sound absorbing panels of different colours makes this material aesthetically acceptable. The wide availability reduces the cost of production of the panels, and more importantly, the material used is completely recyclable. It was also found that the Odeon software provides a good prediction of the room acoustic correction. The model calibration with the software Odeon was shown to produce acceptable results for the reverberation time T_{30} and the EDT.

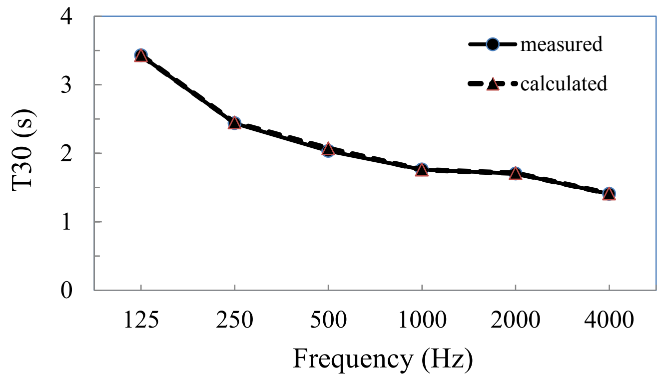

Figure 9. T_{30} measured and calculated values

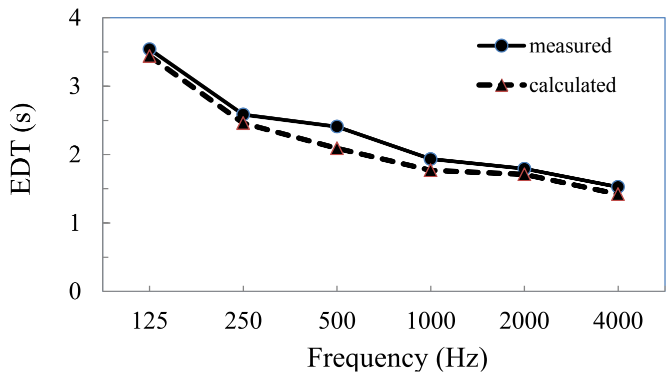

Figure 10. EDT measured and calculated values

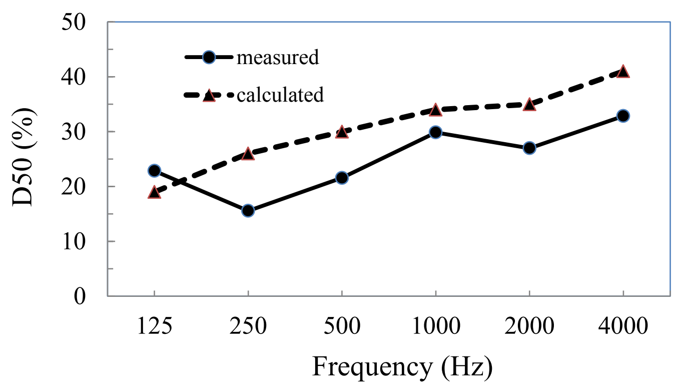

Figure 11. D_{50} measured and calculated values

Figure 12. Sound absorbent panels inserted in a classroom

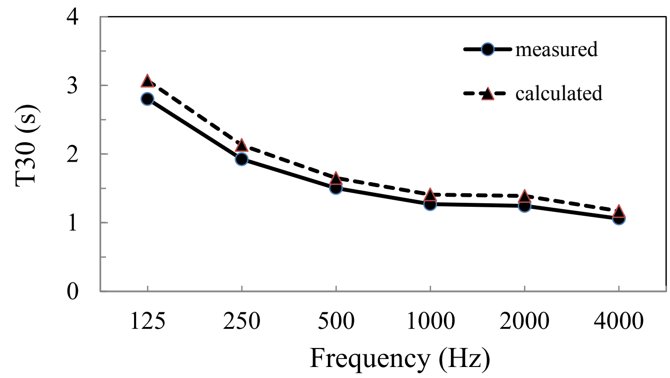

Figure 13. T_{30} measured and calculated values

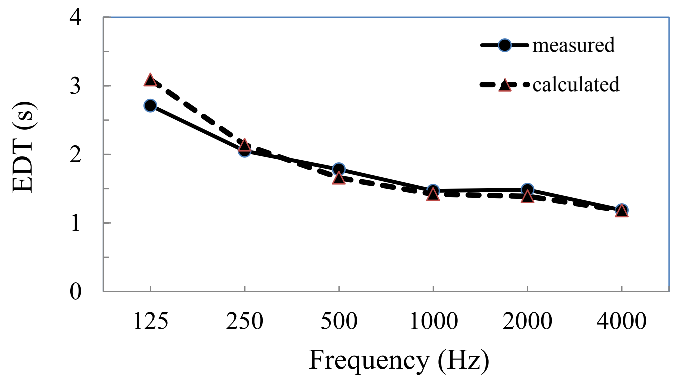

Figure 14. EDT measured and calculated values

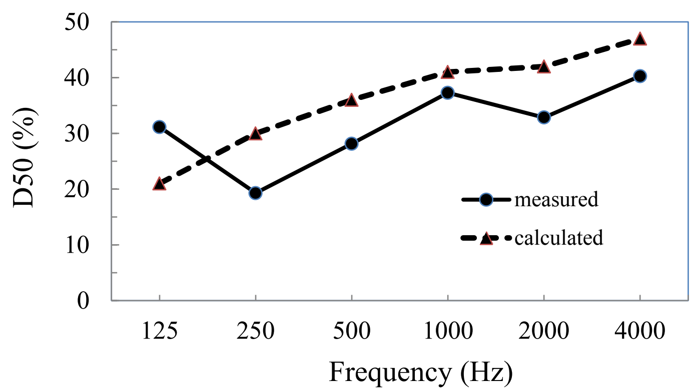

Figure 15. D_{50} measured and calculated values

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Inter-Noise 2014

MELBOURNE AUSTRALIA 16-19 NOVEMBER 2014

The Australian Acoustical Society will be hosting Inter-Noise 2014 in Melbourne, from 16-19 November 2014. The congress venue is the Melbourne Convention and Exhibition Centre which is superbly located on the banks of the Yarra River, just a short stroll from the central business district. Papers will cover all aspects of noise control, with additional workshops and an extensive equipment exhibition to support the technical program. The congress theme is *Improving the world through noise control*.

Key Dates

The dates for Inter-Noise 2014 are:
Abstract submission deadline: 10 May 2014
Paper submission deadline: 25 July 2014
Early Bird Registration by: 25 July 2014

Registration Fees

The registration fees have been set as:

Delegate	$840	$720 (early bird)
Student	$320	$255 (early bird)
Accompanying person		$140
Congress Banquet	$130pp	

The registration fee will cover entrance to the opening and closing ceremonies, distinguished lectures, all technical sessions and the exhibition, as well as a book of abstracts and a USB containing the full papers.

The Congress organisers have included a light lunch as well as morning and afternoon tea or coffee as part of the registration fee. These refreshments will be provided in the vicinity of the technical exhibition which will be held in the main foyer of the Congress Centre. Already, over 40 exhibition booths are booked by overseas and local exhibitors. We are also pleased that Ortech Industries are once more Gold sponsors and that CSR Bradford and Pyrotek are Bronze Sponsors. A few more sponsors are in the pipeline, so if you wish to participate as a Sponsor (some Gold, Silver and Bronze opportunities are still available) or in the exhibition, it is suggested that you contact Dr Norm Broner at NBroner@globalskm.com very promptly or for more details, refer to the Congress website www.internoise2014.org

The Congress Banquet is not included in the registration fee, however, as it will have a strong Australian theme and feature the opportunity for delegates to take photographs of themselves with native Australian animals, it should prove to be a major attraction.

Technical Program

Several interesting discussion sessions are being developed for the Congress, including the question "Should wind turbine sounds be regulated similarly to other sources of community noise?" Also under consideration is the multi-disciplinary application of lightweight constructions to buildings and passenger vehicles. Other special sessions will involve active noise control, sound propagation in outdoor and urban situations, maritime noise and people's reaction to noise and vibration. Workplace health and safety issues, vibro-acoustics, buy quiet and modern acoustic materials are a few more of the 100 potential sessions now listed on the Congress website.

The website also gives details of the six exciting distinguished lectures which forms part of the technical program. These include talks on sound visualization and manipulation, aircraft noise, soundscape and the impact of building acoustics on speech comprehension and student achievement.

Abstract submission commences in January using the Congress website while the paper template will also be available on this site. The closing date for abstracts is 10 May, 2014, and this date is firm and will NOT BE EXTENDED. So please ensure your abstracts are submitted early. Registration is also through the Congress website. Don't forget that the early bird registration closes on 25 July 2014 so book early.

More details at www.internoise2014.org