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DIDACTIC AND SUSTAINABLE PROGRAM FOR THE RESOLUTION OF ACOUSTICS PROBLEMS IN SCHOOLS

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Abstract

It has been verified that there are, in Portugal, some Schools, Basic and Secondary, with different Acoustics problems. It is also verified that Acoustics (Sound) is part, in Portugal, of the School program of Physics-Chemistry (8th grade) and Physics A (11st grade). Thus, it was thought to develop, in a perspective of Social Responsibility of a company specialized in Acoustics, a Program to incentive and support the Teachers of Physics-Chemistry and / or Teachers of Physics A, of Schools with Acoustics problems, to obtain more skills in Acoustics and being able to assume the responsibility of executing – with the support of a company specialized in Acoustics - the Program at the School, in order to, with the involvement of students and / or the school community: 1) characterize properly the school's acoustics problem; 2) explain to students of Physics-Chemistry (8th grade) and / or Physics A (11st grade), in detail proportional to their age and respective school program on Sound, which are the principles of acoustic engineering involved in the acoustic characterization performed; 3) to develop a technical model for simulating the situation in order to be able to define and scale the necessary acoustic correction solutions; 4) explain to the same students as in previous "2)" point, which are the principles of acoustics engineering involved in the acoustics simulation performed; 5) seek to find sustainable "home-made" solutions and "home-made" ways to characterize their acoustics performances, which allow the school community to be involved, and / or find people / companies, especially in the School area, who can sponsor the acquisition of sustainable acoustics professional materials duly characterized, to be implemented in the School, to the extent necessary, with a view to solving the acoustics problem; 6) involve, with due care and risk management, the school community in the solutions implementation; 7) with involvement and explanation to the students, characterize, according to good acoustic engineering practice, the results obtained after the implementation of the solutions.

The purpose of this paper is thus to expose the general principles of this Didactic and Sustainable Program for the Resolution of Acoustics Problems in Schools in Portugal – Basic and/ or Secondary – as well as the exposition of some results already obtained in an test case, which can thus serve as a guide to the cases that eventually come to apply to the Program and to be selected, as the Program, for now, is open to applications once a year, and of these applications only one is selected for execution.

1. INTRODUCTION

The program is published on the SCHIU website, at the following address: www.schiu.com/programa-escolas.

Applications are open until December 31, 2021.

It is intended that the candidates describe, as well as possible, the acoustic problem that affects the school, and that the Physical Chemistry (8th grade) and/or Physics A (11st grade) Teachers are available to coordinate the implementation of the program in a didactic and sustainable way, with the acoustics technical support of SCHIU.

SCHIU reserves the right to select the candidacy that is most urgent and/or most viable of implementation, duly communicating the decision to all candidates.

2. PILOT PROGRAM

2.1. MEASUREMENTS

It was found that there are many complaints from teachers and students, regarding the acoustics of the Sports Pavilion of Poet Emiliano da Costa School, in Estoi, which belongs to the Pinheiro e Rosa Schools Group, Faro.

The pavilion is located at the following geographic coordinates: 37°05'32.1"N 7°53'43.9"W.

The Physical Chemistry Teacher Zélia Ramos was available to coordinate a Pilot Program for didactic and sustainable resolution of the detected acoustic problem, with the acoustics technical support of SCHIU, in particular from its General Director Vitor Rosão. Both sign this paper.

It was thus decided to carry out measurements of the pavilion's Reverberation Time, with the presence of students. It was explained to the students, in a simple manner and geared to their age, which procedure was being used. Essentially bursting of balloons, which sound remains inside the pavilion with some decay over time. The sound decay is measured by the sound level meter. The students witnessed the measurements being taken and asked several questions.

Figure 1 illustrates a photographic note of one of the classes that witnessed the acoustics measurements and illustrates also the test equipment. Figure 2 shows a more general photographic note of the Pavilion’s interior.

In classroom, it was explained to different classes, in different sessions, that in Portugal there are legal acoustic limits for the Reverberation Time of Sports Pavilions. These limits are found in Article 9 of Decree-Law 96/2008 [1], which is transcribed (free translation):

“***Article 9 Sports venues***

1 — Inside sports venues, considered to be normally furnished and unoccupied, the reverberation time, T, corresponding to the arithmetic mean of the values obtained for the octave bands centred on the 500 Hz, 1000 Hz and 2000 Hz frequencies, must meet the following conditions, in which V refers to the interior volume of the enclosure in question:

a) $T_{500\ Hz-2\ kHz} \leq 0{,}15\ V^{1/3}$;

b) $T_{500\ Hz-2\ kHz} \leq 0{,}12\ V^{1/3}$*, if the spaces are equipped with a public broadcasting system for sound messages.*

2 — The determination of the reverberation time must be carried out in accordance with the provisions of the applicable Portuguese standard or, if this does not exist, the European or international standard.

3 – In in situ assessments aimed at verifying compliance with the building's acoustic requirements, an uncertainty factor, I, associated with the determination of the quantities in question, must be considered.

4 – The building, or any of its parts, is considered to comply with the applicable acoustic requirements when the value obtained for the reverberation time, T, minus factor I in the value of 25% of the regulatory limit, meets the regulatory limit”.

Since the Pavilion in question does not have a system for broadcasting sound messages and since it has a volume of around 14520 m^3, the applicable legal acoustic limit is as follows:

$$T_{500Hz-2000Hz} \leq 3.66 \text{ s (without uncertainty factor correction)} \qquad (1)$$

$$T_{500Hz-2000Hz} \leq 4.58 \text{ s (with uncertainty factor correction)} \qquad (2)$$

It was explained, in a Classroom, that there is a standard with indications on how to measure the Reverberation Time *in situ*. This standard is NP EN ISO 3382-2, part 1 and 2 [2,3].

Figure 1. Photographic notes of one of the classes that witnessed the tests and photographic notes of the equipment.

Figure 2. More general photographic note of the pavilion's interior.

The measurements carried out thus followed the referred standard. In short:

a) In the presence of 2 persons (acoustic technicians); exemplary measurements were taken in the presence of students, but these were not the measurements used.

b) Omnidirectional sound source (balloon burst), having generated a sound pressure level sufficient to produce decay curves with the minimum necessary dynamic range without being contaminated by the influence of background noise.

c) Signal recording with sound level meter operating with an integration time of 0.02s.

d) The "Engineering" method was selected as the degree of accuracy, for defining the number of measurement and measurement points, as follows:

   a. Sound source-microphone combinations: 6.

   b. Sound source positions: 2.

   c. Microphone positions: 5 (6 measurements taken at 5 different points; 2 measurements were taken at the centre point, 1 for the source in position 1 and another for the source in position 2).

The simplified scheme of the measurements performed is shown in Figure 3.

The results obtained through the *in situ* measurements for the Reverberation Time (*T*) are shown in Table 1.

Table 1. Results obtained for the Pavilion Reverberation Time.

Measurement positions →	**PM1**	**PM2**	**PM3**	**PM4**	**PM5**	**PM6**	**Média**
***T* [s] →**	7.12	7.39	7.33	7.21	7.40	7.25	**7.28**

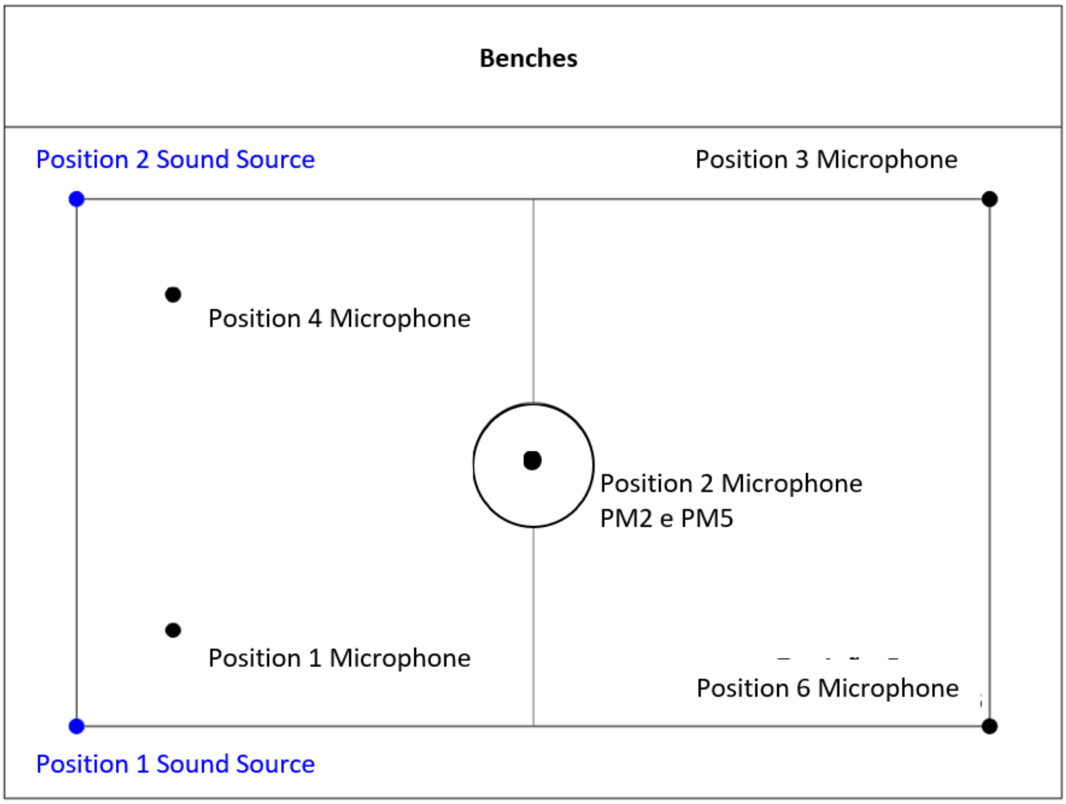

Figure 3. Simplified layout of source and measurement positions

Thus, it can be seen that values obtained clearly demonstrate that the pavilion's average Reverberation Time (7.28 s) is far above the applicable legal acoustic limit (3.66 s, without uncertainty factor; 4.58 s with uncertainty factor) which justifies the different existing complaints, either by Teachers or by Students.

As an example, and for a better understanding of the calculation performed, and the fact that the values vary with the frequency band in question, Figure 4, Figure 5, and Figure 6, presents three impulsive decays obtained in the measurements, for the bands of 500Hz, 1000Hz and 2000 Hz.

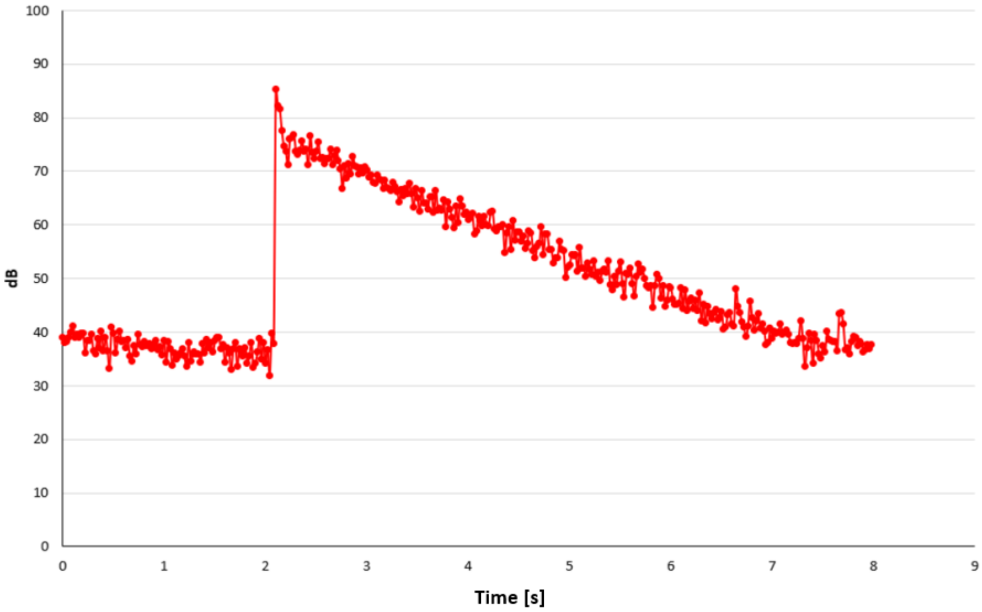

Figure 4. 500Hz Pavilion Impulse Response Example

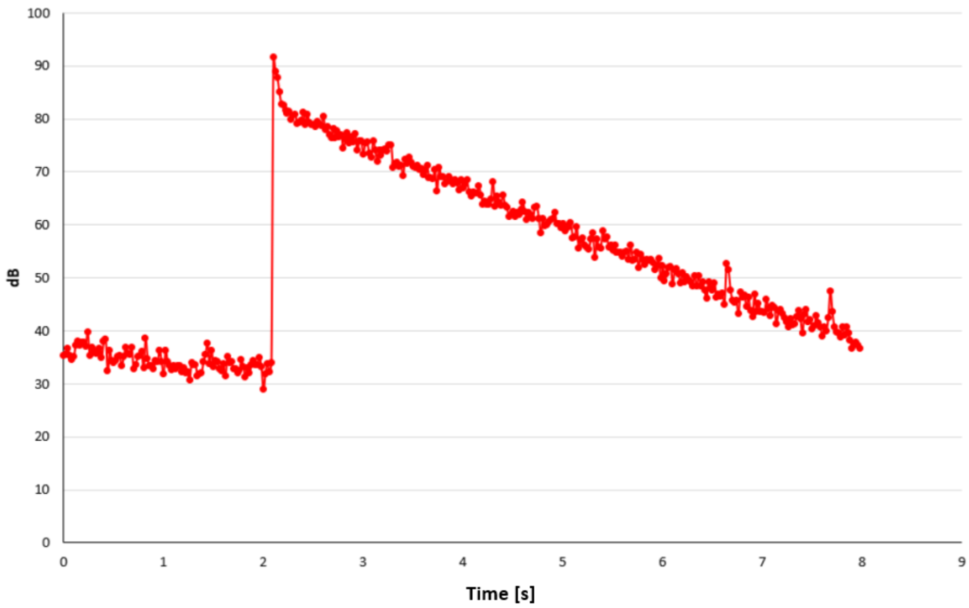

Figure 5. 1000Hz Pavilion Impulse Response Example

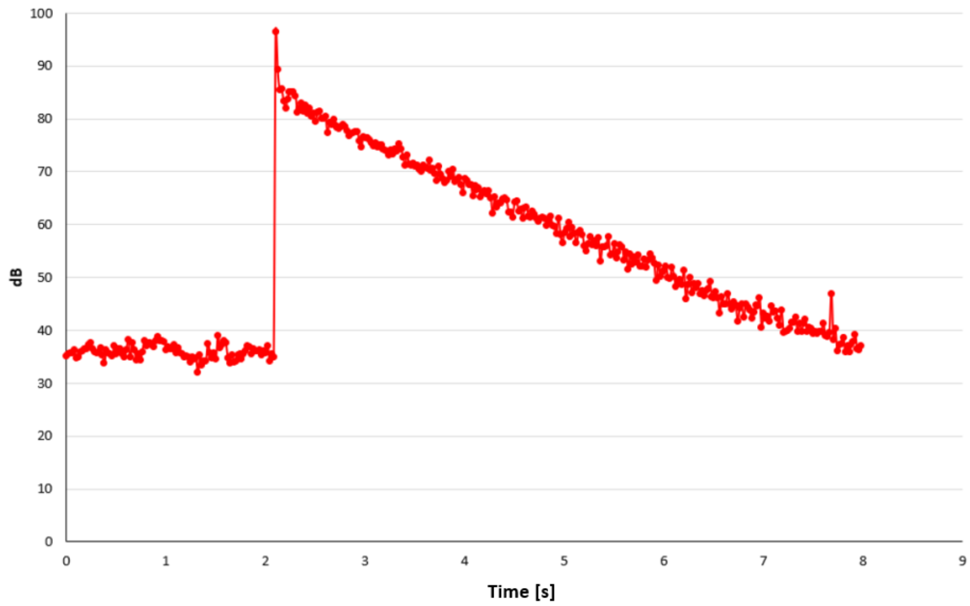

Figure 6. 2000Hz Pavilion Impulse Response Example

2.2. MODEL

Regarding the Reverberation Time forecast, SCHIU has a spreadsheet, developed based on EN 12354-6 [4,5], where the following basic data were considered:

- Dimensions of the Sports Pavilion:
  - Length: 44 m.
  - Width: 33 m.
  - Height: 10 m.
  - Empty room Volume: 14520 m^3.
  - Temperature: 20 ºC.
  - Humidity (0 -1): 0.6.
- Irregular Sound Absorption.
- Construction elements – sound absorption coefficients (α) considered according to the values stipulated in table B.1 of Annex B of EN 12354-6 standard [4]:
  - Walls – Concrete plastered brick:

    500 Hz: α = 0.01 | 1000 Hz: α = 0.02 | 2000Hz: α = 0.02

    Total wall area considered: 1540 m^2;

- Floor: Hard floor covering:

  500 Hz: α = 0.04 | 1000 Hz: α = 0.05 | 2000Hz: α = 0.05

  Total floor area considered: 1452 m^2;

- Ceiling: Ceiling with metal trusses. For the ceiling surface, due to the uncertainty of the value of α to be assigned, it was adjusted in order to obtain in the end a Reverberation Time similar to that obtained in the *in situ* measurements carried out:

  500 Hz: α = 0.26 | 1000 Hz: α = 0.16 | 2000Hz: α = 0.06

  Total ceiling area considered – 1452 m^2.

Thus, taking into account all the aforementioned inputs for the calculation, the following Reverberation Time value was obtained, similar to the value obtained in the *in situ* measurements:

- $T_{500\ Hz-2\ kHz}$ = 7.3 s.

2.3. SOLUTION

To "improve" the Reverberation Time of the space in question, the sound absorption capacity of its surfaces must be increased.

According to the model developed, it is more effective to increase the sound absorption of the top surfaces (walls behind the goals, shown in the images in Figure 7).

Figure 7. Scheme of the proposed location for the placement of sound absorbing materials.

It is therefore recommended to place absorbent material with sound absorption characteristics similar to "Curtain, woven material = 0,4 kg/m^2" (see table B.1 of Annex B of EN 12354-6 [4]), that is, with at least the following sound absorption:

- 500 Hz: α = 0.70; 1000 Hz: α = 0.90; 2000Hz: α = 0.95.

The recommended typology of placement of sound absorbing material is shown, in light blue, in Figure 7.

In order to make the solution to be implemented more sustainable, the School decided to ask the students to provide each one, through their families, a pillowcase, which will be placed inside rock wool (sound absorbing technical material), to be hung in the pavilion at the indicated locations.

A sponsor was sought for the supply of the sound absorbing material. The company Acustekpro (https://www.acustekpro.com/) offered to provide the necessary rock wool *pro bono*.

For reasons of the Pandemic, and others, it has not yet been possible to install the solution, which is the missing step – and what brings greater expectations.

New developments will be published on the Program's website: www.schiu.com/programa-escolas.

3. CONCLUSIONS

It is hoped that the didactic and sustainable program for the resolution of acoustics problems in schools can be in fact useful for school communities that have acoustic problems. According with the pilot program developed, it is believed that it is possible, as intended, to involve teachers and students, in a way that not only seeks to solve the concrete acoustics problem, but also to increase the community's knowledge of acoustics.

Acknowledgements

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Poet Emiliano da Costa School thanks the initiative and technical support provided by SCHIU in solving the detected acoustic problem.

SCHIU and Poet Emiliano da Costa School, would like to thank Acustekpro, in the person of its Director Pedro Teixeira, for the kindness of its availability.

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