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# THE *ACUSTILAB*
# A SMALL EDUCATIONAL DOUBLE REVERBERANT CHAMBER

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**ABSTRACT**

This paper presents the *ACUSTILAB*, an educational physical tool designed by the authors to be used by civil engineering students in laboratory classes regarding environmental and building acoustics. The *ACUSTILAB* is a fully functional scale model (about 1:2) of a double reverberant chamber with 1.5 x 3.5 x 1.4 $m^3$. Its main use is to help teach the practical concepts of reverberation time and sound insulation and the effects of their variability by the visible use of different materials. This wheeled concrete model has its interior divided in two chambers by a movable separation that can be quickly changed according with the desired type of measurements. The upper enclosure simulates a slab to be used for structure borne transmission analysis. The *ACUSTILAB* is assisted by commercially available computer software to control the *Reverberation Time*, *Dn.w (STC)* and *Ln,w (IIC)* tests using a separate large screen to be visible by all the students surrounding the model during the classes.

## 1. INTRODUCTION

One of the most important environmental problems today is NOISE. The first protection against the intrusion of noise in our homes and workspaces is the built envelope. To design and build theses envelopes is mainly the work of civil engineers. For these reasons, noise is an environmental issue that ought to be included in the Civil Engineering curricula.

In the Faculty of Engineering of the University of Porto, the five-year degree in Civil Engineering has three courses involving acoustics and environmental noise in different levels of engagement:

- *Building Physics* (3rd year, 1st semester) in which one third of it is about Acoustics;
- *Environmental and Building Acoustics* (5th year, 1st semester) - option course - entirely about Acoustics;
- *Seminar in Building Construction* (5th year, 2nd semester) - with option in Acoustics.

There is also one course (*Building Acoustics*) on the M.Sc. course in Building Construction.

With the publication and use of the new Portuguese Noise Code [1] and the "Code of the Buildings Acoustics Requirements" [2] there is a need for all future buildings to have an "acoustics project". This can be done by a civil engineer as recently stated by the Portuguese Association of Engineers (*Ordem dos Engenheiros*) in a letter sent to all municipalities. This qualification is given to all civil engineers based upon the knowledge achieved during their university years. Therefore it is of great importance that the civil engineering curricula have a very effective system of teaching this subjects mainly where it regards to the practical behaviour of sound in buildings.

The study of acoustics requires the knowledge and understanding of a large physical background and that is not possible to be easily transmitted in the very short number of classes available. Year after year it was seen that many students do not catch the basics of the most important phenomena involved. Regarding *Noise* and *Buildings* the most important physical concepts to teach are the Reverberation Time (*RT*) and the Sound Insulation (airborne and structure-borne). These are not easily understood if only mathematical equations and pictures in overheads transparencies are used. There is a need to make the students "see" the phenomena and "play" with the involved main variables.

The possible use of tests in real dwellings are very time consuming and do not allow the opportunity to experiment several hypothesis and to check their immediate effect.

These are the reasons for *ACUSTILAB*, an educational physical tool designed by the authors to be used by civil engineering students in laboratory classes regarding room acoustics.

## 2. DESCRIPTION

The *ACUSTILAB* is a fully functional scale model (about 1:2) of a double reverberant chamber with 1.5 x 3.5 x 1.4 $m^3$ (see Figure 1). Its main use is to help teaching the practical concepts of reverberation time, sound insulation and the effects of their variability by the visible use of different materials.

It is made of 0.07 x 0.10 x 0.22 m plain ceramic bricks finished with 0.02 m mortar in each face (see Figure 2). The concrete slab has a 0.10 m thickness and is moved with the help of a rolling-crane. The *ACUSTILAB* is supported by a steel frame base made by H-222 of 0.22 m height. The total weight is about 3500 kg and the cost (without the equipment) is about 6000 €.

This wheeled concrete model has its interior divided in two chambers by a movable separation that can be quickly changed according with the desired type of measurements. The upper enclosure simulates a slab to be used for structure borne transmission analyses.

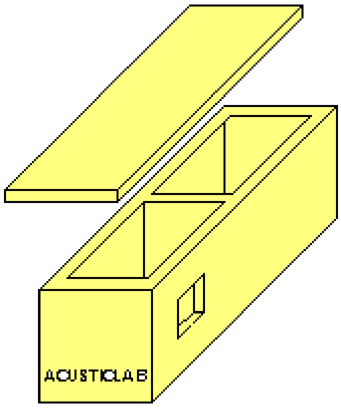


Figure 1: *ACUSTILAB* drawing.

Figure 2: The *ACUSTILAB* during construction.

In the chamber's interior there is a metallic ring prepared to tightly fix the partitions that we want to test. The system is prepared to handle also double partitions with airspace in between.

A double pane window is included in the *ACUSTILAB* for all the students to check its interior and gives also the opportunity for the professor to speak on the advantages of double framed windows and double-glazing windows (see Figure 3).

In the receiving room of the chamber several materials can be put to increase the sound absorption (like little furniture, curtains and other "toys"). This allows the students to check immediately their effect in the reverberation time values and indirectly in the measured sound insulation.

The main interest of this group of small reverberant chambers is to give the students the possibility to test during a 2-hour time slot of a practical class, a few different types of partitions between the two chambers (for airborne sound insulation) or several floor coverings on its cover slab (for the structure borne sound transmission).

The *ACUSTILAB* is assisted by commercially available computer software to control the *RT*, *Dn.w (STC)* and *Ln,w (IIC)* tests using a separate large screen to be visible by all the students surrounding the model during the classes. A custom made software could also be designed.


Figure 3: The *ACUSTILAB* - definitive look.

## 3. MEASUREMENTS

### 3.1 Equipment

The equipment needed to use the *ACUSTILAB* is shown in Table 1.

Table 1: Equipment needed to use with the *ACUSTILAB*.

| MAIN EQUIPMENT | ALTERNATIVE (AND CHEAPER) EQUIPMENT |
|---|---|
| Sound speaker | Battery powered tape recorder |
| Microphone | (no alternative) |
| Sound level meter | Integrated custom built software |
| Laptop computer | Table PC |
| Percussion generation equipment (tapping machine) | Hand help percussion equipment |
| Total cost of about 11.000 € | Total cost of about 3.000 € |

### 3.2 Results

The measurement procedures will follow, in general, the related Portuguese standards NP-EN-140-1 [3] and NP-EN-140-6 [4].

The results are immediately displayed in the laptop display using a spreadsheet (like *EXCEL* or *LOTUS*) and projected onto a wide screen next to the *ACUSTILAB* to allow all the students simultaneously to check for the results and differences.

The Figure 4 shows an example of airborne sound insulation measurements with four types of partitions under test.

The students can continue their hands-on experience on a following class, calculating the single-number quantities *Dn,w* (*STC*) and *Ln,w* (*IIC*) using the standards NP-EN 717-1 [5] and 717-2 [6]. These quantities can be also calculated by the software, in situ (during the experiment).

The base reverberation time values (empty chambers) are shown in Figure 5 together with an example with the interior surface floor covered with a sound absorption material.

The entire chamber (empty) can also be used to teach the students to calculate the sound absorption coefficient ($\alpha$) of materials. This method can be used by them in a separate practical class.

## 4. CONCLUSION

The use of this educational tool has begun in the academic year of 2001/2002 for all the 3rd-year students (7 classes with about 200 students). The overall impression achieved with this first use fully confirms the didactic interest of this tool.

The use of this new pedagogic method can have an economy of about 7 to 8 hours of teaching time (in comparison with the standard in-class method) and with a clearly improved rate of effective learned concepts and skills.

With further years of use, more data will be collected to evaluate the effectiveness of this tool.

## 5. ACKNOWLEDGEMENTS

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## 6. REFERENCES

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**ACUSTILAB**
**CALCULATION** ***Airborne sound insulation***
***Dn,w or R'w (dB)***

| Freq. (Hz) | 125 | 250 | 500 | 1000 | 2000 | 4000 | *Dn,w* |
|---|---|---|---|---|---|---|---|
| **L source (dB)** | 100,2 | 106,8 | 103,3 | 101,0 | 95,3 | 80,8 | |
| **L reception (1)** | 83,9 | 87,3 | 81,2 | 79,4 | 74,9 | 55,3 | |
| **dL(1)** | **16,3** | **19,5** | **22,1** | **21,6** | **20,4** | **25,5** | |
| | | | | | | | |
| **L reception (2)** | 80,8 | 88,0 | 80,1 | 78,4 | 74,3 | 53,4 | |
| **dL(2)** | **19,4** | **18,8** | **23,2** | **22,6** | **21,0** | **27,4** | |
| **L reception (3)** | 79,0 | 86,0 | 80,0 | 78,0 | 72,0 | 53,4 | |
| **dL(3)** | **21,2** | **20,8** | **23,3** | **23,0** | **23,3** | **27,4** | |
| **L reception (4)** | 78,8 | 85,6 | 80,1 | 77,8 | 71,0 | 53,4 | |
| **dL(4)** | **21,4** | **21,2** | **23,2** | **23,2** | **24,3** | **27,4** | |

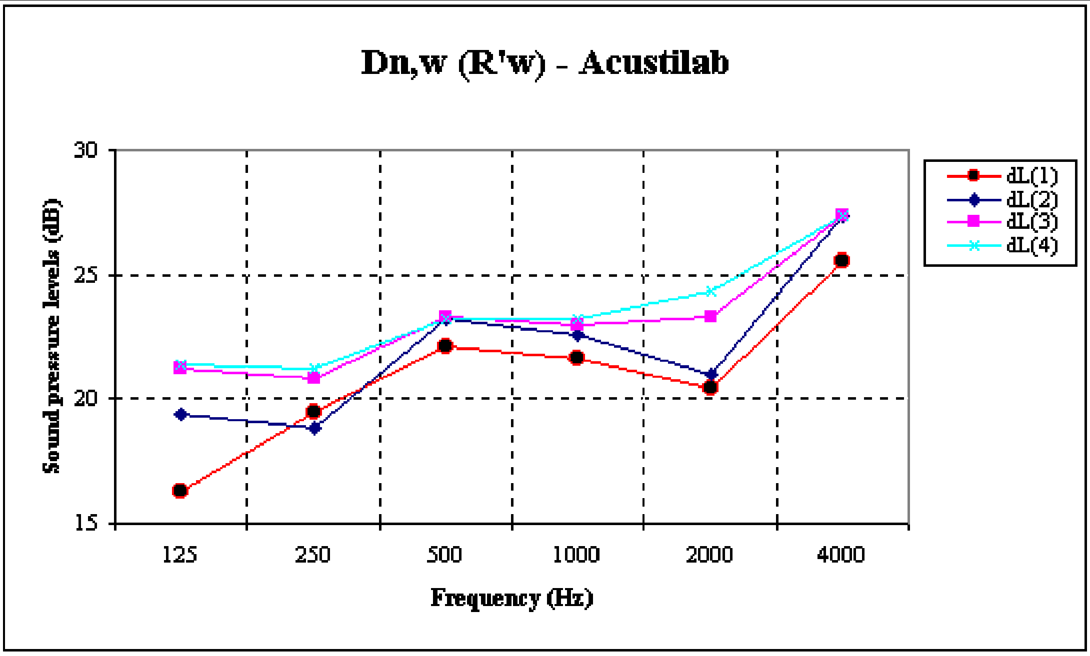


Figure 4: Typical example of an output for airborne sound measurements.

**ACUSTILAB**
**CALCULATION** ***Reverberation Time***
***RT (s)***

| Freq. (Hz) | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|
| ***RT*** **(s) empty chamber** | 1,9 | 2,1 | 2,3 | 1,3 | 1,1 | 0,9 |
| | | | | | | |
| ***RT*** **(s) material 1 (absorp.)** | 1,3 | 1,4 | 1,2 | 0,7 | 0,5 | 0,4 |

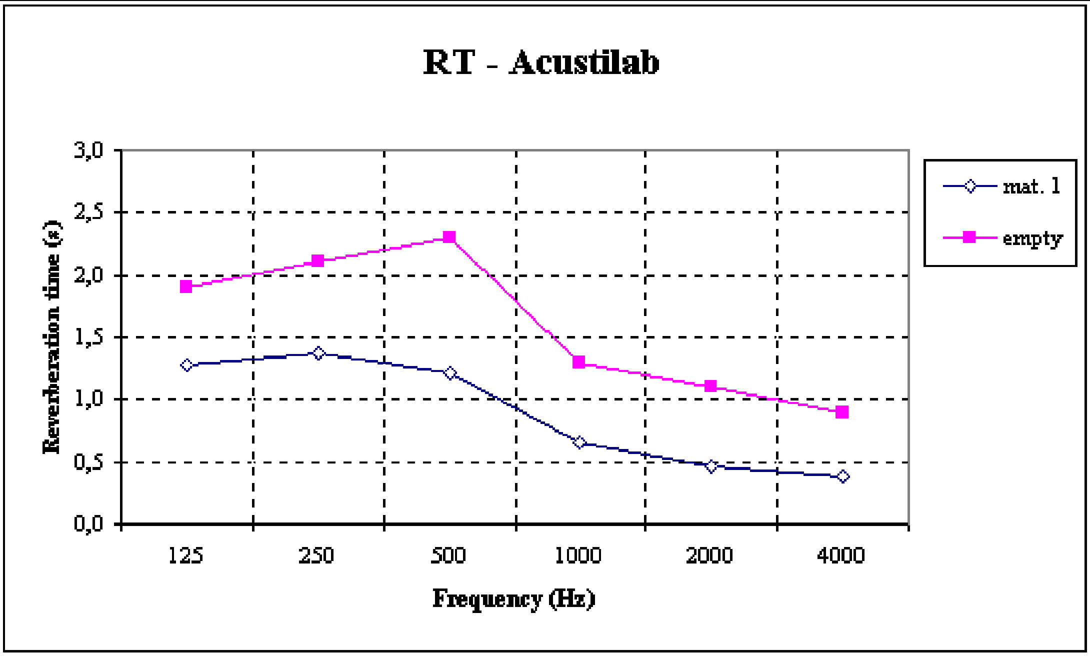


Figure 5: Typical example of an output for reverberation time (*RT*) measurements.