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Session 2pAAa: Architectural Acoustics

2pAAa12. From Portugal to Florida, and the Newman award

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I was 31 years-old when, in 1991, I left the University of Porto to study architectural acoustics at the University of Florida with Professor Gary W. Siebein. In 1994, I finished my Ph.D., I got the Robert Bradford Newman Award, and my career changed. In fact, that 1994 would be the BIG BANG of my future life. Personally, academically, and scientifically, my Universe blew up and began expanding. What I learned and what I taught in the 17 years after that (and what the architectural acoustics changed in Portugal and Southern Europe) is the subject of this paper.

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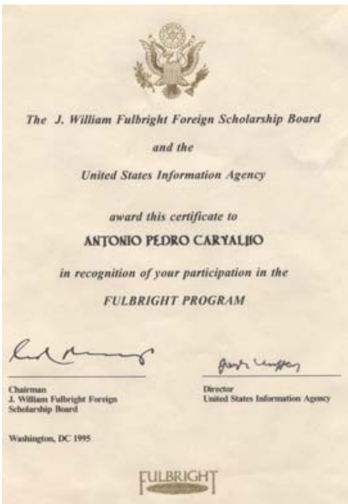
1 - Introduction

Once upon a time, in 1991, when I was 31 years old, I got a Fulbright scholarship to pursue Ph.D. studies in the USA (Fig. 1). I left the University of Porto and from 1991 to 1994 I engaged in classes and research in the University of Florida under the Supervision of Professor Gary W. Siebein (Fig. 2). And finally, under the wings of a guardian angel, on December 17, 1994... (Fig. 3).



The J. William Fulbright Foreign Scholarship Board
and the
United States Information Agency
award this certificate to
ANTONIO PEDRO CARVALHO
in recognition of your participation in the
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Chairman
J. William Fulbright Foreign Scholarship Board

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United States Information Agency

Washington, DC 1995

FULBRIGHT

Fig. 1 (left) - Fulbright scholarship.
Fig. 2 (right) - The author at the Laboratory of Acoustics in the University of Florida with a model of the Oporto's Sports Pavilion.

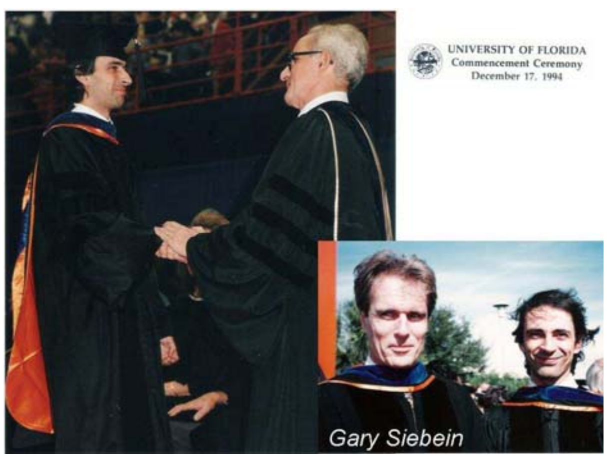
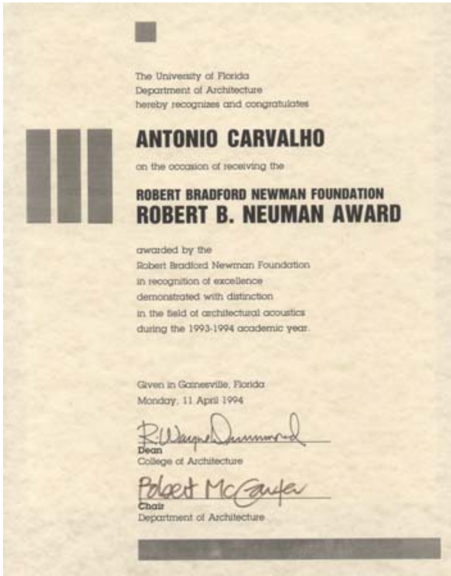


Fig. 3 - The author, his supervisor (Profesor Gary W. Siebein) at the UF Commencement, Dec. 17, 1994.

2 - The Big Bang

In 1994, I finished my Ph.D. [1], I got the Robert Bradford Newman Award (Fig. 4), and my career changed. In fact, that 1994 would be the *BIG BANG* of my future life. Personally, academically, and scientifically, my Universe blew up and began expanding.

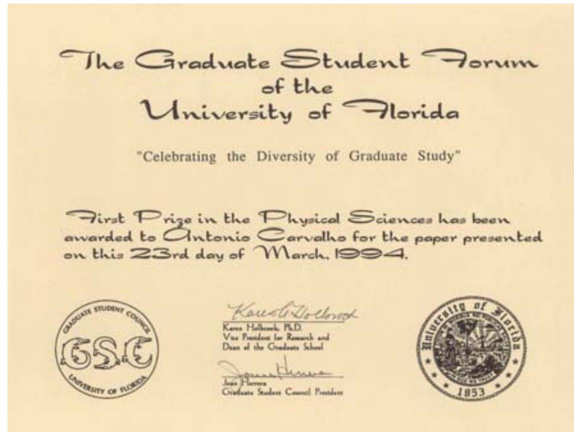
On that same year I received the First Price (in Physical Sciences) in the Graduate Student Forum of the UF (Fig. 5).


The University of Florida
Department of Architecture
hereby recognizes and congratulates
ANTONIO CARVALHO
on the occasion of receiving the
ROBERT BRADFORD NEWMAN FOUNDATION
ROBERT B. NEUMAN AWARD
awarded by the
Robert Bradford Newman Foundation
in recognition of excellence
demonstrated with distinction
in the field of architectural acoustics
during the 1993-1994 academic year.

Given in Gainesville, Florida
Monday, 11 April 1994

Dean
College of Architecture

Chair
Department of Architecture


The Graduate Student Forum
of the
University of Florida

"Celebrating the Diversity of Graduate Study"

First Prize in the Physical Sciences has been awarded to Antonio Carvalho for the paper presented on this 23rd day of March, 1994.

Fig. 4 (left) - The Robert Newman Award given to the author
Fig. 5 (right) - First Prize in the Physical Sciences awarded to the author at The Graduate Student Forum of the University of Florida

3 - The Acoustics World

The old home planet was disappearing but others appeared... like a new “space ship” (Fig. 6).
A new Galaxy, The Acoustics World, as in site.
It was Time to be member in several acoustic associations and engage in their meetings (Fig. 7).
Superior life forms were encountered that are beacons in this path (Fig. 8).
It was Time to see and learn (much) more (Fig. 9).
It was the Time to help others on their own path (Fig. 10 and 11).

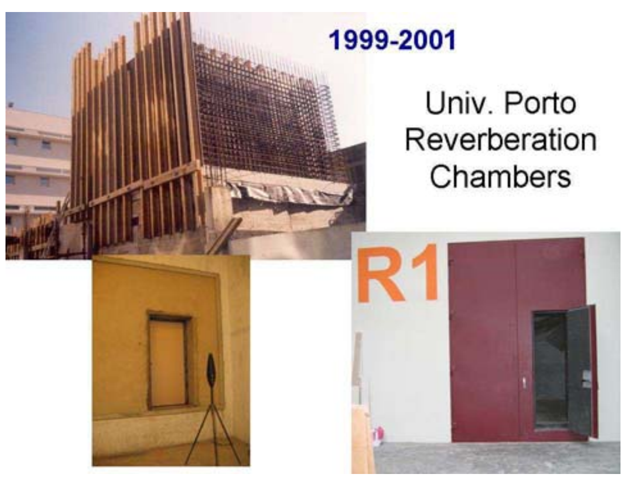


Fig. 6 - The University of Porto (College of Engineering) reverberant chambers

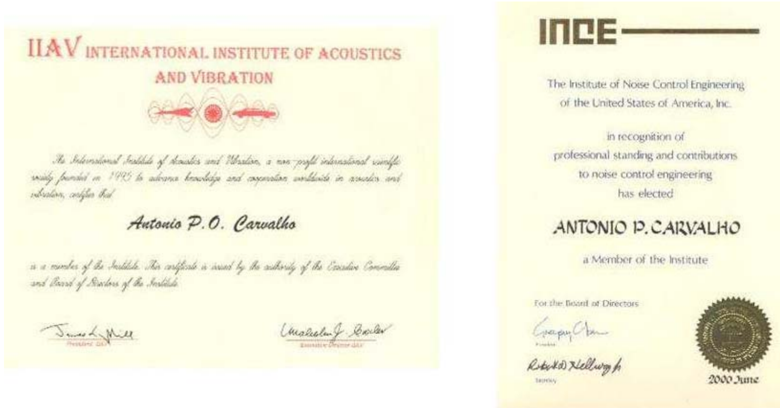


Fig. 7 - Member of diverse acoustic associations like ASA, IIAV, INCE, etc.

Fig. 8 - The author with Leo Beranek at the MIT

Fig. 9 -The author at diverse research trips.

Fig. 10 - The author in several graduations.

Since then I supervised a total of 56 students (completed and underway graduated students), 48 M.Sc. 48 and 8 Ph.D. Some also received their own awards like Ms. Beatriz Pinto (Fig. 11).


ACOUSTICAL SOCIETY OF AMERICA

OUTSTANDING YOUNG PRESENTER AWARD IN NOISE

presented to

BEATRIZ PINTO

for her paper

Dancing the aerobics "hearing loss" choreography

presented at the Fall 2002 meeting in Cancun, Mexico, 2-6 December 2002

Fig. 11 - ASA 2002 Cancum meeting award to Ms. Beatriz Pinto (U. Porto).

It was then Time to talk and to present papers all over the world (Fig. 12).

Fig. 12 - Meetings all over the world.

It was Time to teach.
In 1995, for the first time, a *B.Sc.* in Portugal has a Course in Acoustics – Civil Eng. *Acoustics and Noise Control.* Now (at the Univ. of Porto) I have two 50 h courses: B.Sc./M.Sc. in Civil Engineering (*Environmental and Buildings Acoustics)* and B.Sc./M.Sc. in Environmental Eng.(*Environmental Acoustics).*
A new tool was invented to give better classes, *ACOUSTILAB*, a small reverberant chamber (Fig. 13) [2].
Something must have worked because I got two pedagogic awards given by the College of Engineering under the opinion of students (Fig. 14).
It was the Time to build a career (Director of the Laboratory of Acoustics, Tenure achieved, and Associate Professor).

Fig. 13 - *Acoustilab*, a small reverberant chamber for educational purposes [2].


DIADAFEUP
19 DE NOVEMBRO 08

A Faculdade de Engenharia da Universidade do Porto atribui a
António Pedro Oliveira de Carvalho
o
Prémio de Incentivo Pedagógico

O Director da FEUP
Prof. Doutor Carlos Costa

A FEUP SOU EU

DIADAFEUP
18 DE NOVEMBRO 09

A Faculdade de Engenharia da Universidade do Porto atribui a
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o Prémio de Incentivo Pedagógico

O Director da FEUP
Prof. Doutor Carlos Costa

A FEUP SOU EU

U.PORTO

Fig. 14 - Pedagogic awards given to the author in 2008 and 2009 by the College of Engineering (U. Porto)

4 - Research Program in Church Acoustics

It was a Time to learn, and a ***Research Program in Church Acoustics*** begun [3].
Its main goals were, for instance:

- How to predict acoustic parameters from geometric features;
- How to predict subjective ac. parameters from objective ac. parameters;
- How church interior acoustics evolved with time and architectural styles;
- How SRS change the speech intelligibility;
- What is the acoustical behavior of Baroque gilded woodcarving (Fig. 15);
- How Catholic churches compare (acoustically) with mosques and synagogues.

Fig. 15 - Sound absorption of baroque gilded wood carving (in reverberation room)

The typical approach in many of this research was based in statistical modeling, where a large sample of *N* "similar" cases (churches) is used to measured several acoustic parameters(RT, EDT, C_{80}, D_{50}, RASTI, NC, LAeq, etc.) and geometric parameters (volume, area, width, length, height, etc.). From those, relations and regressions are found using simple and/or general linear models in order to achieve a relationship that from 1 or more parameters one can get a predicted value of an acoustic parameter (Fig. 16).

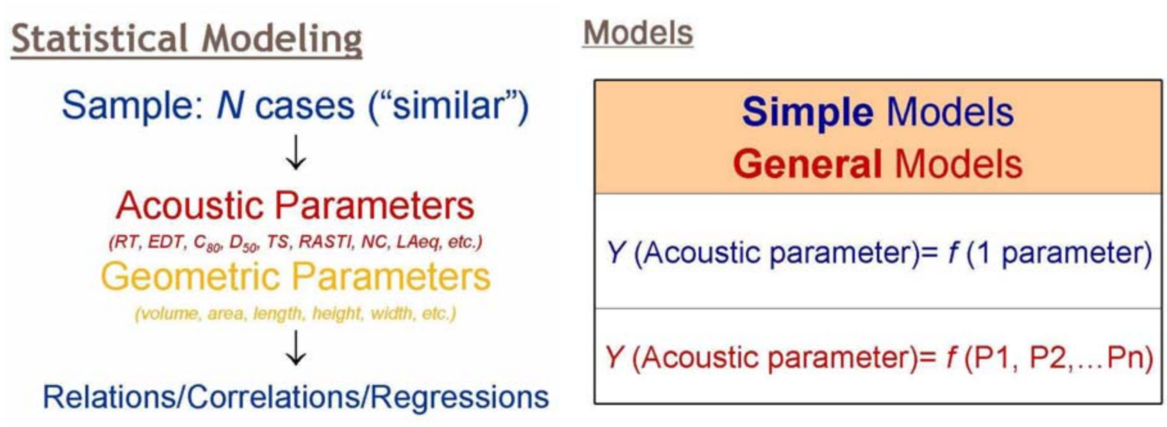

Fig. 16 - Statistical modeling and models used in research

As an example of these many topics (and dissertations) let's see the *Analysis of RT values in churches according to country and architectural style* [4]. A sample of about 400 churches in nine countries was used (Germany D, Greece G, Italy I, Poland PL, Portugal P, USA, Spain E, Switzerland CH, and Yugoslavia (Serbia) YU). Fig. 17 shows the data (Volume/RT) and the best fit equations found. Regression equations (*RT* vs. *V*) are consistent (except USA and PL) and generally $RT \approx \ln(Volume) - 5$.

Many other conclusions were found for example that the RT values decrease from Gothic to Baroque and increases from Baroque to Neoclassic.

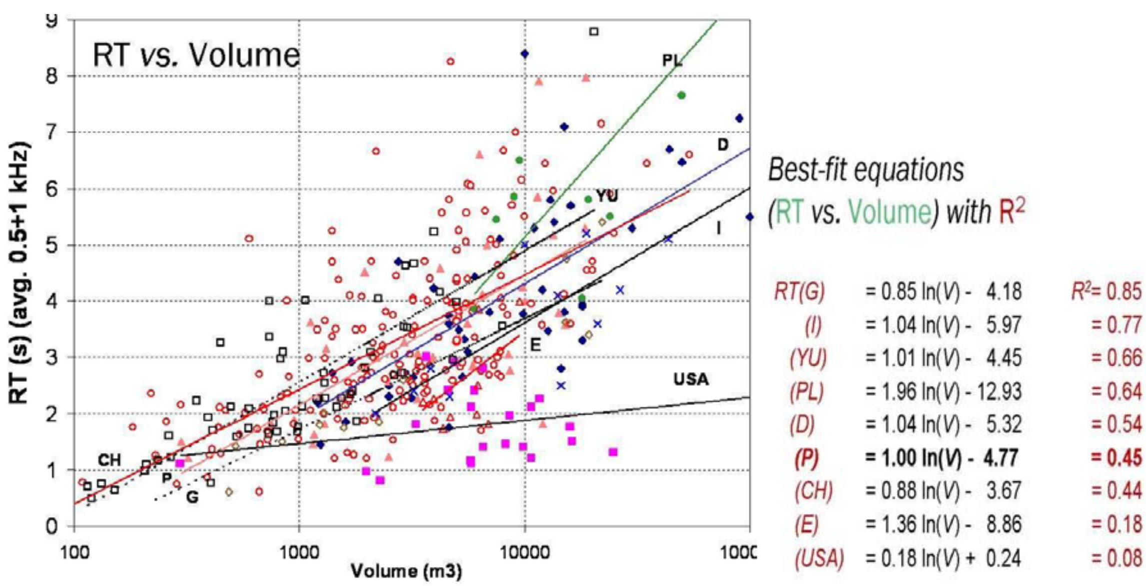

Fig. 17 - Analysis of RT values in churches according to country and architectural style with the best-fit equations [4].

Other example is the Acoustic characterization of rehabilitated cloisters [5,6] (Fig. 18) and a few conclusions are present at the Fig. (19).
As a sample of conclusions: Rehabilitation by closure of open galleries with glass implies (if no other modification is done in the galleries): a reduction on RASTI ≈ 0.08 to 0.10 and an increase on RT (500-1k Hz) ≈ 1.3 to 1.5 s.

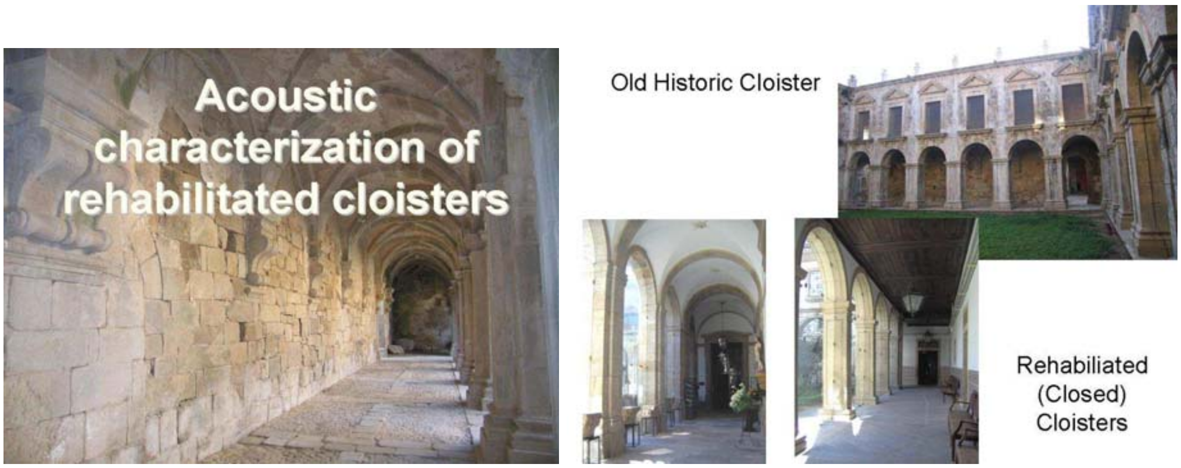

Fig. 18 - Acoustic characterization of rehabilitated cloisters [6]

ACOUSTICAL VS. ARCHITECTURAL PARAMETERS (*Sg, V, Sp* and *A* refer to half cloister: 2 perpendicular galleries)	R^2
RASTI = 0.000993 *Sg* – 0.000279 *V* + 0.54272	0.97
RT125 = 0.0162 *Sg* – 0.0874 (*A125_250*) + 5.281	0.96
RT1k = 0.1088 *H* + 0.00338 *V* – 0.06130 (*A500_1k)* + 2.9824	0.96
RT2k = 0.05845 *H* + 0.00283 *V* + 0.3054 *W* – 0.04100 (*A2k_4k*) + 1.601	0.99
RT4k = 0.04124 *Sp* + 0.2217 *H* – 0.2658 *L* – 0.02236 (*A2k_4k*) + 2.586	0.99

ΔRASTI & ΔRT *VS*. ARCHITECTURAL PARAMETERS DUE TO CLOSING GALLERIES WITH GLASS	R^2
ΔRASTI = 0.02076 *H* – 0.00015 *V* + 0.00150 (*A125-250*) – 0.1480	0.97
ΔRT125 = – 0.1757 *H* – 0.8152 *W* – 0.06617 (*A125-250*) + 7.2851	0.96
500 = – 0.1168 *Sp* + 1.023 *L* – 0.1090 (*A125-250*) – 1.414	0.95
1k = 0.5271 *H* + 0.1155 *L* – 0.06916 (*A500-1k*) -1.2243	0.94
2k = 0.08206 *H* + 0.00280 *V* – 0.04144 (*A2k-4k*) + 0.8434	0.99
4k = 0.03692 *Sp* – 0.2124 *L* – 0.02313 (*A2k-4k*) + 1.5857	0.97

Fig. 19 - Acoustic characterization of rehabilitated cloisters [6]
(H - height, W - width, V - volume m^3, S - surface m^2, L - length, A - Absorption m^2)

Other example is the Comparison of the Acoustics of Mosques and Catholic churches [7] (Fig. 20) where 42 Roman Catholic churches in Portugal were compared with 21 mosques in Saudi Arabia. A few conclusions are presented at the Fig. 20 and 21. Churches have larger RT (1 to 2 s) than mosques; RT growth (by V) is more pronounced in churches; (RA)STI is higher in mosques than in churches (for equal Volume); Mosques have better acoustic behavior for speech intelligibility.

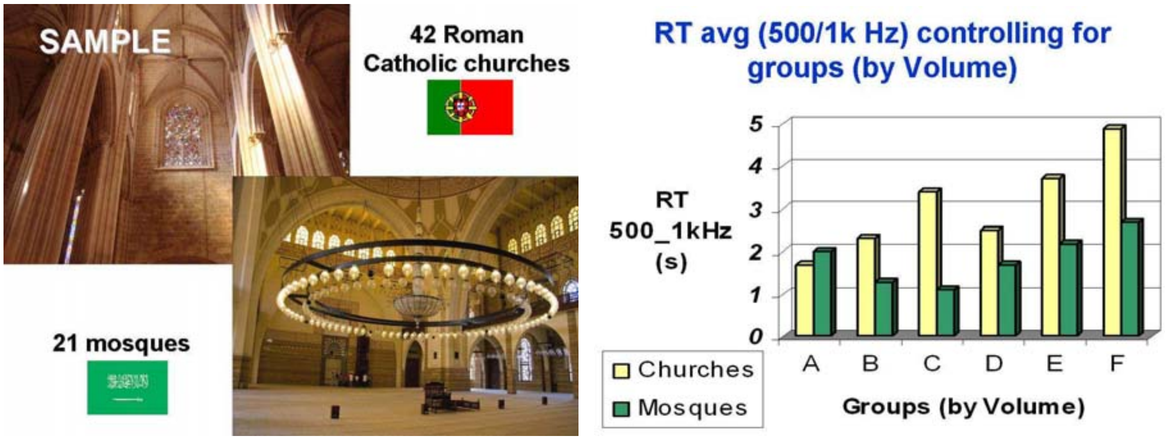

Fig. 20 - Comparison of the Acoustics of Mosques and Catholic churches [7]

Arch. parameter	Equation	R^2
V–Volume (m^3)	$RT = 0.25\ V^{0.3050}$	0.51
H–Height (m)	$= 0.00248\ H^2 + 0.0745\ H + 1.6309$	0.56
V–Volume (m^3)	$RT = -3.01x10^{-9}\ V^2 + 0.000127\ V + 1.38$	0.64
H–Height (m)	$= 1.8084 \ln(H) - 1.1271$	0.65

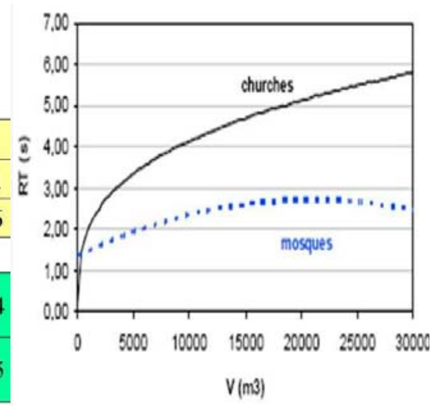

Fig. 21 - Comparison of the Acoustics of Mosques and Catholic churches
(left) Best models RT vs. architectural parameters (above: yellow churches, below: green mosques) and (right) RT vs. Volume [7]

Other example is the Acoustical characterization of the Central Mosque of Lisbon where the goals were to compare the Lisbon Mosque with other mosques (in the world) and with churches in Portugal, with similar volume [8, 9] (Fig. 22). A few conclusions are presented in Fig. 23 and 24.

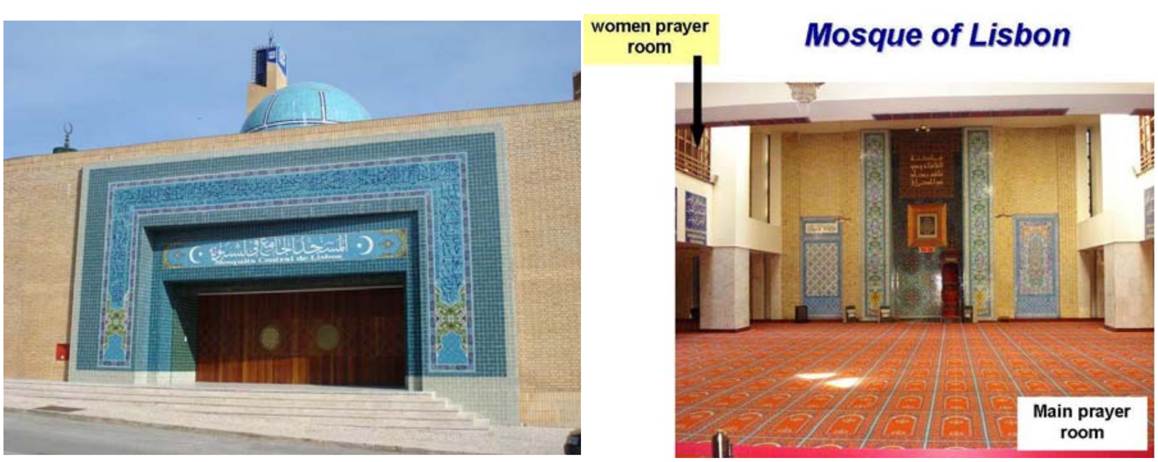

Fig. 22 - Acoustical characterization of the Central Mosque of Lisbon [8, 9]

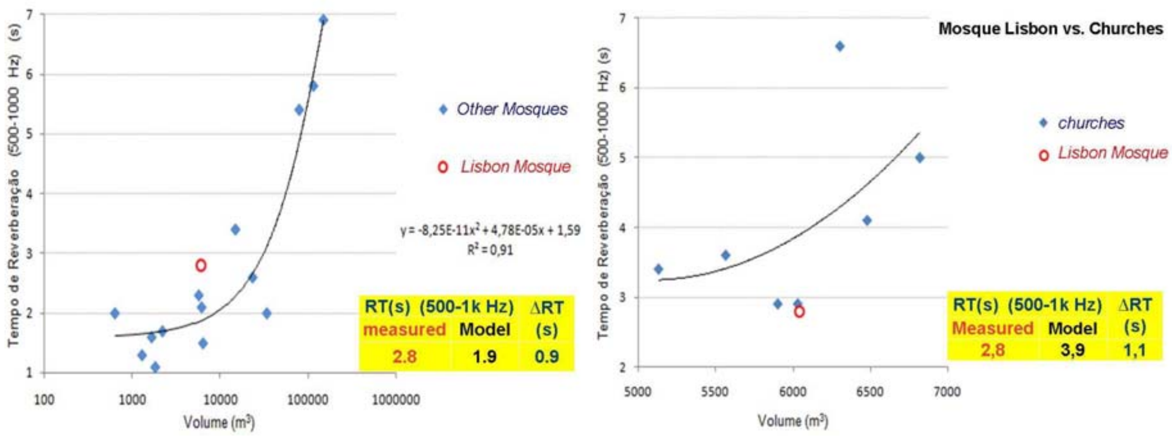

Fig. 23 - Acoustical characterization of the Central Mosque of Lisbon [8, 9]

	RT (s)	RASTI No SRS	Mosque Lisbon Acoustic behavior
Mosque Lisbon	2,8	0,48	
Mosques World	1,9	0,44	worse
Churches	3,9	0,39	better

Fig. 23 - Sample of conclusion for the Acoustical characterization of the Central Mosque of Lisbon [8, 9]

One more example is the Acoustical characterization of courtrooms. Using a sample of 29 courtrooms in Portugal relationships were found among the parameters (Fig. 24). A few conclusions are presented in Fig. 25 [10].

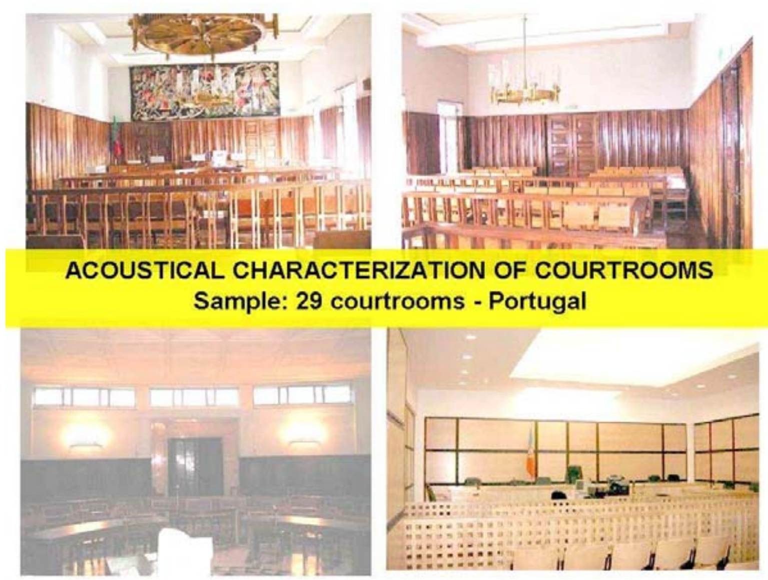

Fig. 24 - Acoustical characterization of courtrooms [10]

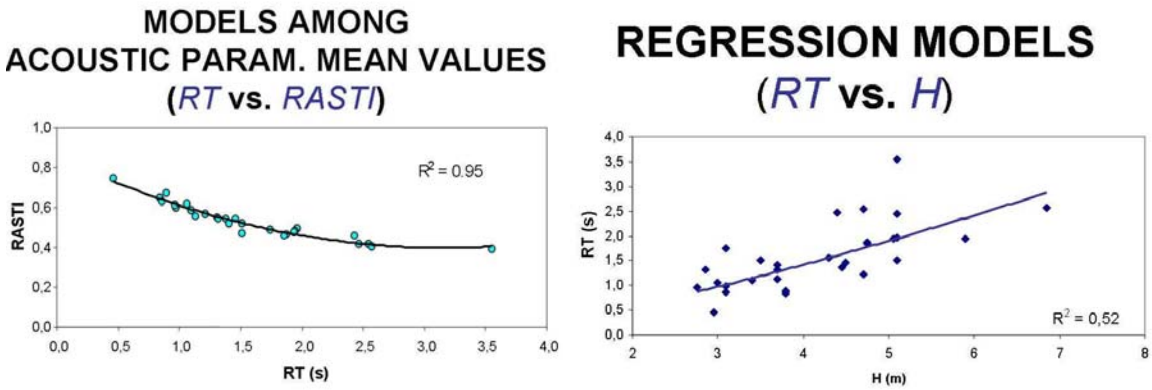

Fig. 25 - Sample of conclusions of the Acoustical characterization of courtrooms [10]

One more example is the Acoustical characterization of libraries. Using a sample of 28 libraries in Portugal relationships were found among the parameters (Fig. 26). A few conclusions are presented in Fig. 27 [11]. Among those *Classic* libraries seem to have a slightly higher *RT*, lower *RASTI* (≈ 0.04) and higher *NC/NR* (≈ 6 dB) than the Modern libraries. However no strong statistical evidence was found to support that *Classic* libraries behave acoustically better than *Modern***.**

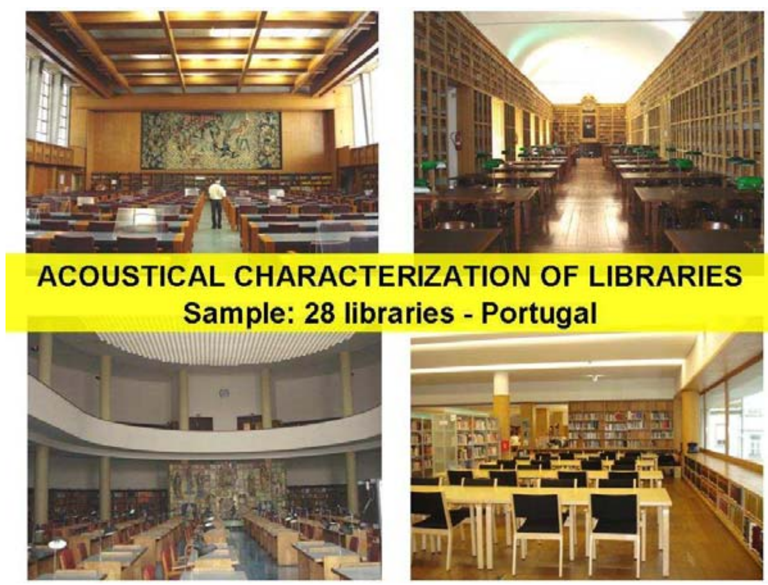

Fig. 26 - Acoustical characterization of libraries [11]

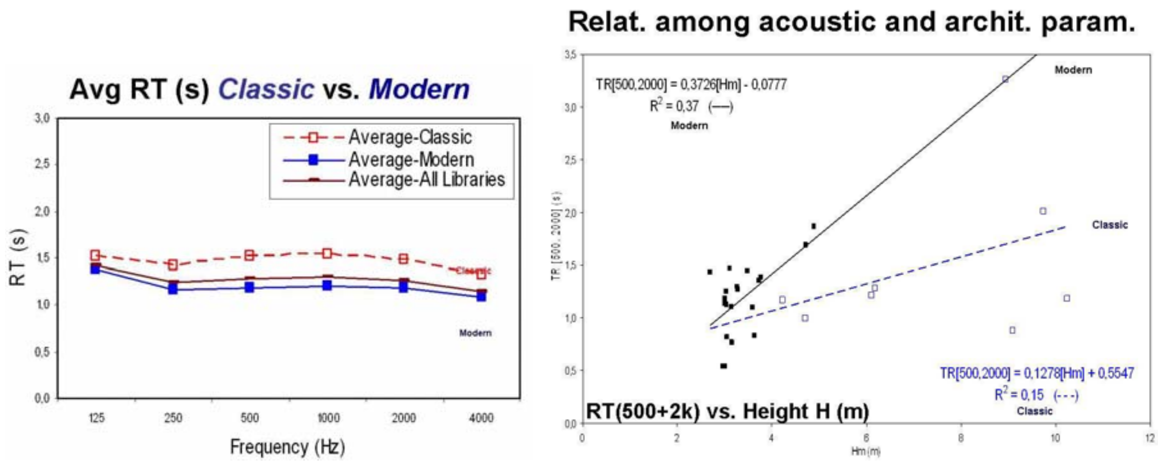

Fig. 27 - Same results from the Acoustical characterization of libraries [11]

And the work continued with many others (Health clubs, school gymnasiums, neonatal intensive care units, dental schools (practice rooms) [12 to 16].

5 - How Acoustics expanded in my backyard... in two decades

In two decades many things changed in the Acoustics education arena. In my backyard many universities began having courses in Buildings and Environmental Acoustics. For instance:

- **Graduated studies in Spain -** M.Sc. (9): University of Cadiz (Environmental Acoustics), University of Extremadura (Evaluation & Management of Envir. Noise), University of Granada (Acoustic Contamination), University of Leon (Acoustical Engineering and Vibrations), European University of Madrid (Architectural and Envir. Acoustics), University Pol. Madrid (Acoustic Engineering in Buildings & in the Environment and Acoustic Engineering in Industry and Transports), University Pol Valencia (Acoustics Engineering), University of Valladolid (Acoustical Engineering and Vibrations), University of Ramon Llull (Architectural and Environm. Acoustics).
- **Graduated studies in Portugal -** University of Porto College of Engineering (FEUP): Courses in the M.Sc. Civil Eng. and Envir. Eng. (Environmental and Building Acoustics, and Environmental Acoustics); T. University of Lisbon (IST) (Acoustic Engineering Diploma, 1 semester); Catholic University College of Engineering (Lisbon): Graduated courses (Building Acoustics, Environmental Acoustics); University of Coimbra Courses in the M.Sc. Civil Eng. and Envir. Eng (Applied Acoustics, Environmental Acoustics); Polit. Inst. Porto (School of Music and Performing Arts): M.Sc. In Applied Electroacoustics (4 semesters).

6 - Conclusion

This was my life after receiving the Acoustic "Oscar", the Robert Newman Award. It changed me and my life. But the path is not over.
... To be continued...

Fig. 28 - From Florida to Porto, again.

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