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Sound absorption control at low frequencies in the new symphonic concert Hall of VillaPrado Valladolid

Victoria Chavez Thielemann

University of Chile & Xu Acoustique, 17, rue Danton, 94270 Le Kremlin Bicêtre, France
v.chavez@yahoo.fr

In large concert halls for symphonic music the sound absorption control at low frequencies is a compromise between acoustics and architecture. Sometimes the architectural approach is imposed over acoustical wills. In this way the acoustician must adapt his work to the architectural choice of finishing materials. Commonly is the case of the wood material's choice (usage of thin wood panels in low density), whose architectural expression is related to orchestra instruments and to the visual warmth.
Nowadays the acoustical trend is to obtain in concert halls the appropriate acoustical "warmth". As known, this acoustical quality in a concert hall is related to the bass sound spotlessness, and an appropriate strength of the bass tones arriving to the audience.
In this context we will present the solutions and constructive compromises realised in the auditorium of Villa Prado in the way to obtain the desired warmness. This concert hall has a "shoe box" shape, a capacity of audience of 1720 seats and it was made completely in wood panels (architect: R.BOFIIL, acoustician: Xu Acoustique, inaugurated in April 2007, Spain).

1 Introduction

The bass frequency absorption control in large concert halls is a challenge if we expect good acoustics'. The principal problem is to find a compromise between architecture proposal style and acoustics' solutions.

In a big number of cases, acoustics' must be subordinated to architectural esthetical proposals. Consequently, the acoustical solutions must fusion with architecture, from where it could grow new solutions, but this process is not easy.
One of the problems of this fusion between architecture and acoustics' comes from the known difficulty to define subjective quality concepts.

For instance, if we take the concept of "warmth" in architecture, we will find that it is closed related to the visual aspects of dimensions, colour and textures. Other than the question of dimensions, warmth is wished to be obtained by designing with colours in orange and yellow not saturated tones (or pastels), and texture as to produce not flat surfaces, using soft textures. That means the opposite of electric colours and hard texture forms. Consequently, that's why wood finishing is considered of architects a very warm material (it was also a reminiscent sense of nature).
In many cases wood finishing is used to attenuate the opposite effect produced by a big space with hard and net forms.
When designing spaces for music's, this idea of wood finishing is semantically added to music instruments material.

In the other hand for acoustics' as describes by Beranek warmth "in music is defined as liveness of bass, or fullness of bass tones (between 75 and 350 Hz), relative to that of the mid-frequency tones (350 to 1400 Hz). Musicians describe as "dark" a hall that has too strong a bass, or whose high frequencies are greatly attenuated"
As called by Baron this is a question of balance: "a hall is described as possessing acoustic warmth if there is adequate sense of bass sound; as an objective measure the relative level of bass compared to mid-frequency sound may be most significant here".
Notably in large concert hall to obtain bass tones richness the massive construction is the best way to do, and that means that over the objective parameter RT a rise at bass is necessary. But, as for the architectural idea of warmth, the degree of bass rise is a taste subject.

Knowing that it is not always possible because of budget and local technical limitations to obtain wood finishing with massive materials, we present the case of Villa Prado, where efforts were made in order to avoid bass absorption due to thin wood panel's architectural choice.

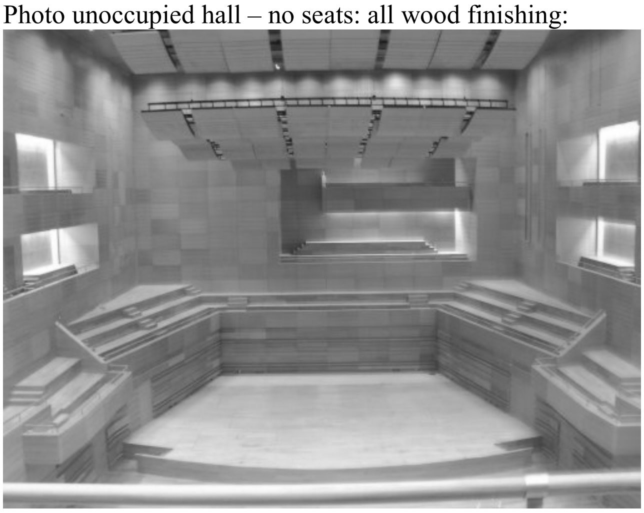
2 Villa Prado Concert Hall characteristics

This concert hall makes part of the Cultural Centre of Villa Prado in Valladolid Spain. It is composed by the main auditorium for concert of 1700 seats, a chamber music hall of 450 seats, drama theatre hall of variable public capacity and the music Conservatory rehearsal rooms.
The building was inaugurated in April 2007, signed Bofill architectura.

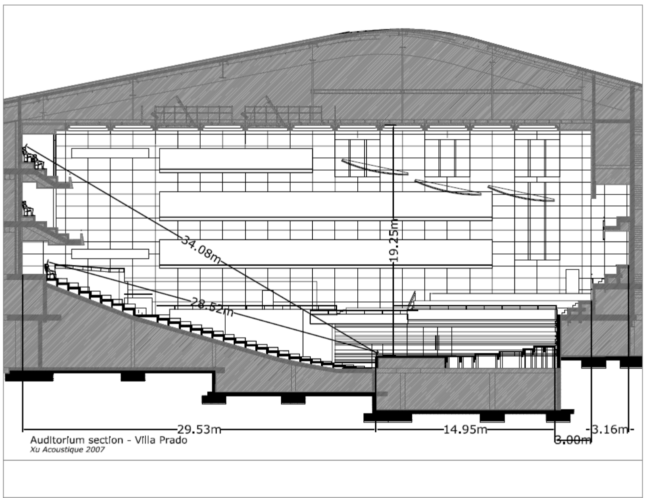
The main concert hall is a shoe box shape hall of around 19750m3, and 1720 seats, in one space (no stage cage).
It has a variable absorption acoustics system over upper part of side walls and twelve slightly curved reflectors are suspended above the stage and their height can be varied mechanically.

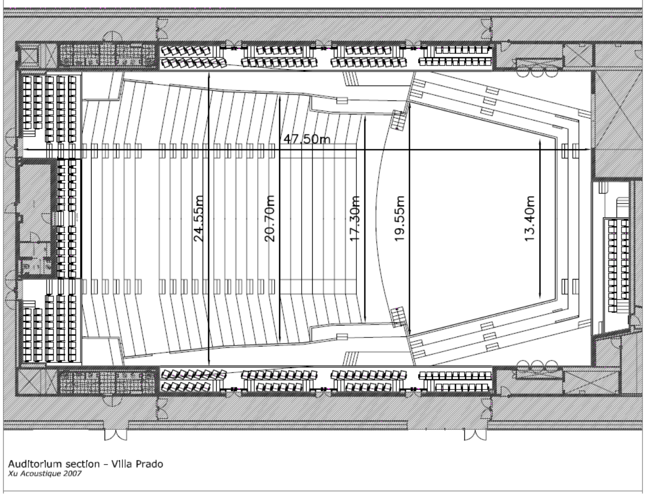
V/N 11,5 m3/p
H stage-ceiling= 19 m.
Distance stage-last main floor range= 28,5 m
Distance stage-last 2nd balcony range= 34 m

Photo unoccupied hall – no seats: all wood finishing:



Section and plan with dimensions:





3 Estimated RT

The estimation of RT according to the volume of the concert hall is:

s/ Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**
RT objective	*2.3*	*2.3*	*2.1*	*1.9*	*1.9*	*1.6*

* 0,1 sec tolerance

With suitable bass ratio of 1,15~1,2.

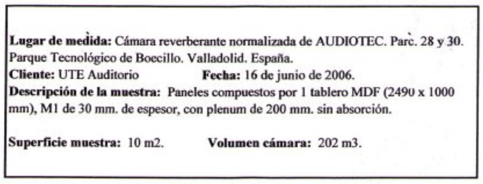
The calculated RT (Eyring formula and Statistical) was the following by using Beranek's data from 1969 for audience absorption:

s/ Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**
RT objective	*2.38*	*2.38*	*2.12*	*1.88*	*1.86*	*1.60*

* Remark: RT considered Beranek's hypothesis 0,39/ 0,57 s to 125/ 250 Hz. But if we consider Beranek's 2003 data 0,62/ 0,72 s to 125/ 250 Hz, the RT rise at low frequencies came down, giving a flat curve.

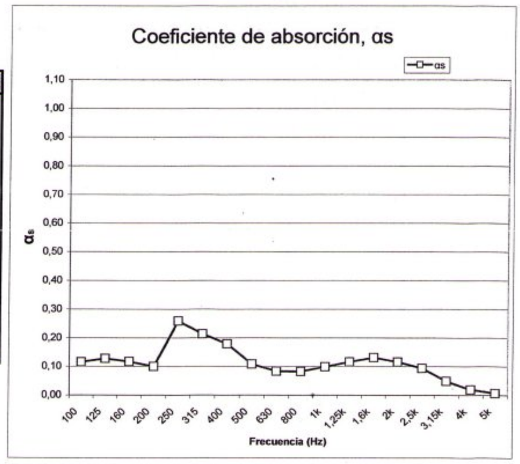
4 Estimation of thin panel's absorption

The prediction of bass absorption is not easy.
For the Villa Prado auditorium analyse the bass absorption was a result of experience observation (M.XU) and documentation as tables of different studies, and some acoustics test made by the constructor in order to corroborate our evaluation.
The following test was made with MDF panel of 30mm thickness and void of 200mm, by ENAC (Spain).


Lugar de medida: Cámara reverberante normalizada de AUDIOTEC. Parc. 28 y 30. Parque Tecnológico de Boecillo. Valladolid. España.
Cliente: UTE Auditorio **Fecha:** 16 de junio de 2006.
Descripción de la muestra: Paneles compuestos por 1 tablero MDF (2490 x 1000 mm), M1 de 30 mm. de espesor, con plenum de 200 mm. sin absorción.

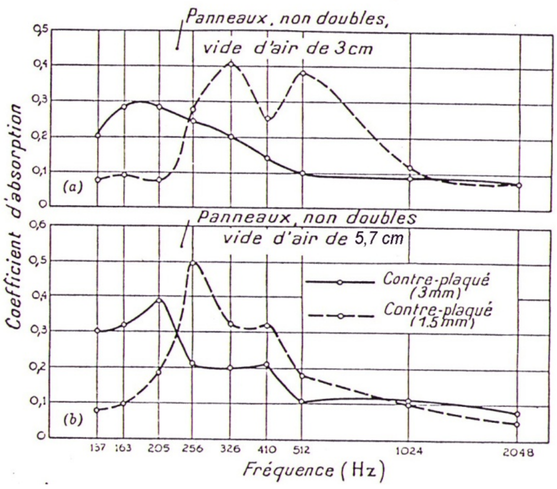
Superficie muestra: 10 m2. **Volumen cámara:** 202 m3.

Frec(Hz)	α_s
100	0,12
125	0,13
160	0,12
200	0,10
250	0,26
315	0,21
400	0,18
500	0,11
630	0,08
800	0,08
1k	0,10
1,25k	0,12
1,6k	0,13
2k	0,12
2,5k	0,09
3,15k	0,05
4k	0,02
5k	0,01



Unfortunately, they don't make the test for one of the present's situations in the auditorium.

Otherwise, it was useful to calculate the absorption coefficient since theoretical absorption comportment curves (like those proposed by Knudsen & Harris underneath) and simplified formula of resonance frequency (no filled with porous absorbent cavity): ***fo= 600/Racine of m*d***, where ***m*** is the panel mass in kg/m2 of the surface, and ***d*** is the cavity distance between panel and wall support.



The proposed panels for a main part of walls and ceiling surfaces were MDF with veneer wood.
Because of coast the 30mm thickness were preferred for an important part of surfaces, which ***fo= ~50Hz***, for 7-8cm of void cavity. That means for our calculation of RT consider around 0,22 - 0,20 absorption coefficient to bass frequencies (125 - 250 Hz).
With this absorption coefficient and with Beranek's data of 1969 for audience absorption, the RT calculation gives a rise to bass, but we know that bass absorption for audience is underestimated in this data.
That's why our estimation is not completely accurate. However, it was useful to analyse this actual subject.

5 Solutions to reduce bass absorption

To reduce absorption due to thin panels of original design, some areas were changed as follows:

5.1 Panels around stage

The concerned area consists of the three stage walls and lengthened to first tree rows at stall level. They are made by MLS diffuser relief (d of 10cm). The material for this one is changed to a complex of 2 layers of gypsum board 15mm, plus 1 layer of MDF panel of 30mm, and the MLS cavities were filled of MDF layers, as shows the photo:

5.2 Ceiling panels

The main false ceiling was made by a complex of 7 glued layers of MDF (total thickness 65mm) with a weight of ~46kg/m², suspended over metallic secondary structure.
It was made and glued by an industrial process to assure the solidity of the composite panel.

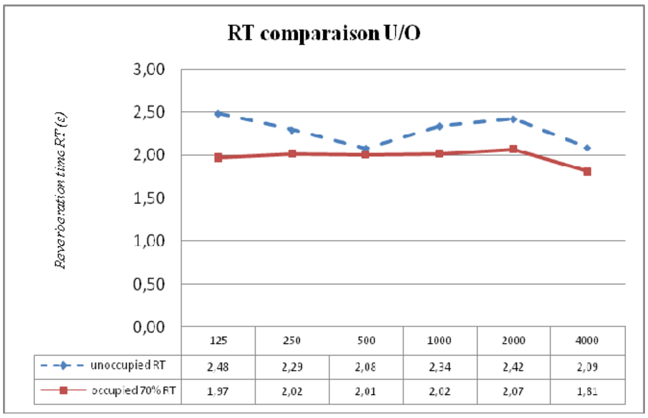
5.3 Side walls panels

It represents the bigger surface of absorption. Some panels with 3cm thickness, void cavity of 7-8cm, could not be changed, and for some places (near the stage) it was possible to increase only to 4cm thickness. So to avoid selected frequency absorption a random disposition of wood joists was made.

6 Measured RT

The measured RT was given for unoccupied conditions and for occupied only 70% (it was measured with software Dirac for impulse response measurement, T20 and T30 average).

unoccupied RT	2,48	2,29	2,08	2,34	2,42	2,09
occupied 70% RT	1,97	2,02	2,01	2,02	2,07	1,81

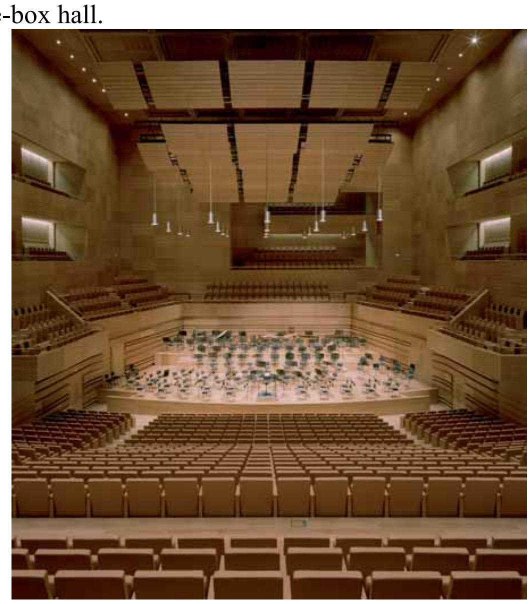


7 Conclusions

The results of measured RT show the really need of massive materials to achieve a good balance at bass tones.
In another hand, the evaluation of audience absorption at low frequencies was an additional point of uncertainly.

However, the critics received are quiet good subjective reactions from musicians and public. Because of other acoustics' parameters not treated here, the acoustics is clear and the spaciousness is good.

Visually, the hall is very sober and comfortably ample. The proportions are naturally agreeable for a classical shoe-box hall.



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