ACOUSTICS OF THE NEW THEATRE AUDITORIUM (TAP) IN POITIERS, FRANCE: CONCERT HALL AND OPERA THEATRE

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1 INTRODUCTION

A new cultural center, now called Théâtre Auditorium de Poitiers or TAP, has been inaugurated on September 6th, 2008. It is the home of one of the most active and prestigious French "Scène Nationale" with a complete cultural programme which includes classical and contemporary music, opera, theatre, dance, variety, jazz. In 2000, an international competition awarded the project to the team of Portuguese architect Joao Luis Carrilho da Graça, including commins acoustics workshop as the acoustical consultant and Hervé Beaudouin as executive architect.


Figure 1: General view of TAP


Figure 2: Facade screens

The building is close to the city center, on a promontory overlooking a deep valley. The Poitiers TAP includes a Symphony Hall with 1020 seats, a theater opera house with 700 seats, a foyer designed for informal concerts, a large orchestra and opera rehearsal room.

The fact that the 2000 competition brief included two halls with distinct functions gave the architects and engineers a rare opportunity: the creation of two major rooms with different architectural and acoustical signatures.

2 THE MAIN ELEMENTS OF THE PROGRAMME

The architectural programme was quite detailed and some excerpts are summarized below.

2.1 The opera theatre

Capacity	700 seats
Uses	Theatre, opera, musical theatre
Mobile orchestra pit	70 m², 40 to 50 musicians
Stage opening	Mobile, width from 14 to 18 m, height 7 to 9-m
Volume	4500 to 5000 m^3
Reverberation time	1,3 to 1,4 sec.
Clarity	$0 < C_{80} < 2$ dB
Computer simulation	All configurations using an approved computer programme
Noise level	NR 20

2.2 The concert hall

Capacity	900 to1100 seats, 100 to 120 musicians, chorus 120
Uses	Symphony, lyric, variety
Stage height	0.90 m above stalls
Orchestra platforms	1,20-m width, percussions 2 to 2,20-m
Rigging	Through the ceiling for lights, speakers and curtains
Volume	11000 to 12000 m^3
Configurations	Variable from 1100 to 600 seats, recordings
Seats	Row-to-row 90-cm, width 55-cm
Morphology	Intimacy between public and musicians; diffusive, non-absorptive, orchestra « shell »; possibility of chorus 1.20-m above percussions; some seats behind the orchestra; no deep balconies; good visibility for unobstructed direct sound
Reverberation time	1,8 to 2,2 sec, variability 15 to 20 %
Clarity	$-2 < C_{80} < 2$ dB
Computer simulation	All configurations using an approved computer programme
Noise levels	NR 20

3 DESIGN AND CONSTRUCTION

The design team proposed for the competition two radically different rooms: a very sober theatre and a more spectacular concert hall. The building itself is a typical example of pure contemporary Portuguese architecture with very simple lines and generous interior volumes. A digital system projects full size pictures and information on cultural events on whole glass facades.


Figure 3: Architectural model

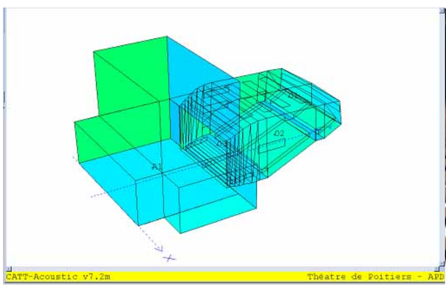

Figure 4: Lateral view


Figure 5: Projection on facade

3.1 The theatre opera house

The elements of the programme corresponded, from the point of view of the acoustician, to an ideal opera house with a reasonable capacity of 700, close to the Galli-Bibiena theatres, a 4500-m^3 volume, a genuine orchestra pit and all the up-to-date stage equipment.

The 20-m width, the tilted walls, a diffusive ceiling and an absorptive back wall generate a relatively long reverberation time with good clarity. The wooden floor of the stalls is built on sleepers. The mobile 90-m² orchestra pit is entirely built in wood, with some fixed and removable absorptive components; its wood floor is built on a damped resonant cavity. The design was tuned on a computer model at the competition stage.



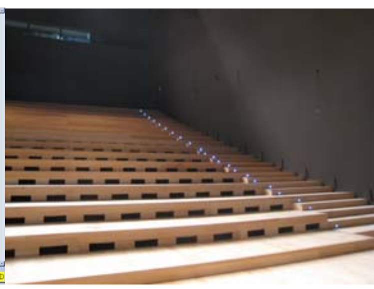


Figure 6: Computer model

Figures 7 and 8: Interior views (under construction)

3.2 The concert hall

The general trend today is to design multi-purpose halls with complex shapes and sloped floors to guarantee, among other things, good visibility of the stage floor for example for dance programs. The Poitiers concert hall, dedicated by priority to music, did not necessarily need inclined stalls. Looking back, one observes that the best concert halls are often horizontal.

Concert hall	**Total number of seats (number in stalls)**	**Horizontal length of stalls (m)**	**Height of stage above stalls (m)**	**Comment**
Amsterdam, Concertgebouw	2206 (1366)	26	1.40	Orchestra risers
Basel, Stadt Casino	1400 (990)	22	1	Orchestra risers
Berlin, Konzerthaus	1575 (768 + chorus 116)	22.5	0.90	Orchestra risers
Bonn, Beethovenhalle	1407 (1030)	29	1.2	No risers
Boston Symphony Hall	2631 (1486)	35 (+ 9m sloped)	1.1	Few risers
Glasgow, St.Andrew's Hall	2133 (1060)	27	1.5	No risers
Leipzig, Neues Gewandhaus	1560 (966)	33	1	Destroyed in WW2
München, Herkules Saal,	1287 (853)	31	1	Orchestra risers
Paris, Cité de la Musique	1100 (variable)	20	1	Orchestra risers
Stuttgart, Liederhalle	2000 (1175)	43	1	Orchestra risers
Wien, Musikvereinsaal	1680 (1032)	24.5 (+ 4.5 m sloped)	1.20	Orchestra risers
Zurich, Tonhalle	1546 (925)	30	0.90	Horizontal ceiling

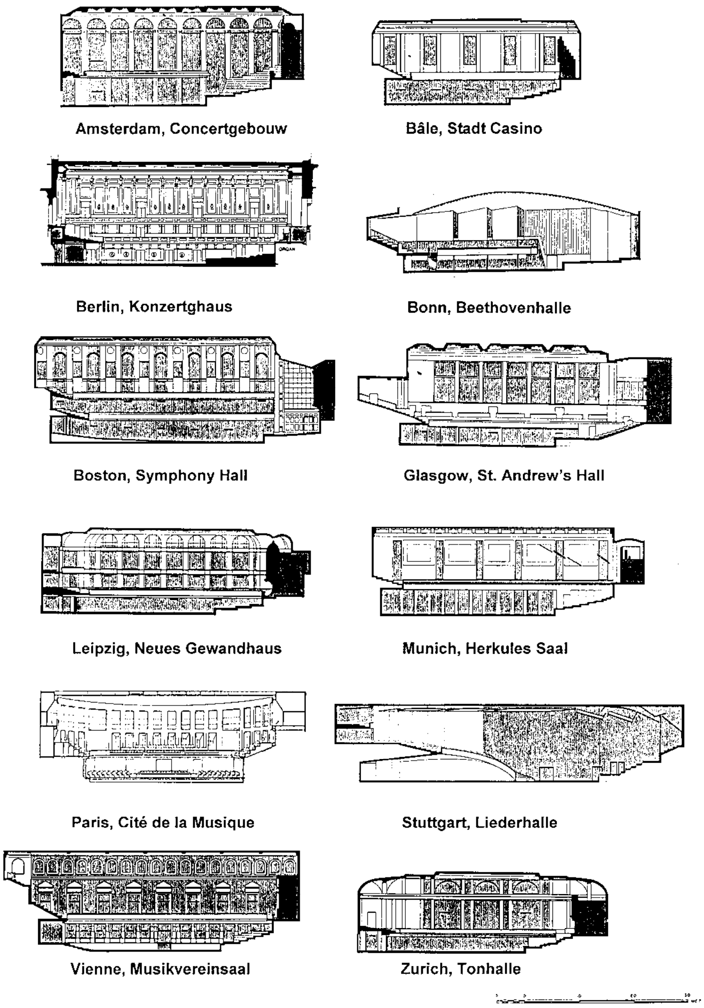


Figure 9: Longitudinal sections of « horizontal » halls

The effects of the stall's angle and of the ceiling's characteristics on a number of classical acoustical criteria were tested in various rooms; the models attempted to take into account the seat and audience angle-dependent diffraction and absorption. An example of the results for a "shoebox" hall with fixed volume and width is given below.

Criteria	Shoebox Horizontal floor and ceiling	Shoebox Tilted floor Horizontal ceiling	Shoebox Tilted floor Tilted ceiling
TR_{Eyring}	1.78 s	1.77 s	1.58 s
EDT	2.06 s	4.85 s	4.70 s
D_{50}	31.8 %	79.4 %	83.0 %
C_{80}	-0.2 dB	6.1	7.0 dB
LEF	36.2 %	3.7 %	13.5 %
T_s	137 ms	87.1 ms	72.5 ms
SPL	65.8 dB	57.2	57.1 dB
G_{10}	6.8 dB	-1.8 dB	- 1.9 dB

Since the simulation showed a better combination of values for a horizontal floor and ceiling, this principle was adopted and, once the usual general parameters such as specific volume, acoustical width, height and length were set, the design was concentrated on the detailed shape and on the location and nature of the diffusive components which, for such a prestigious concert hall, could not be picked off the shelf.

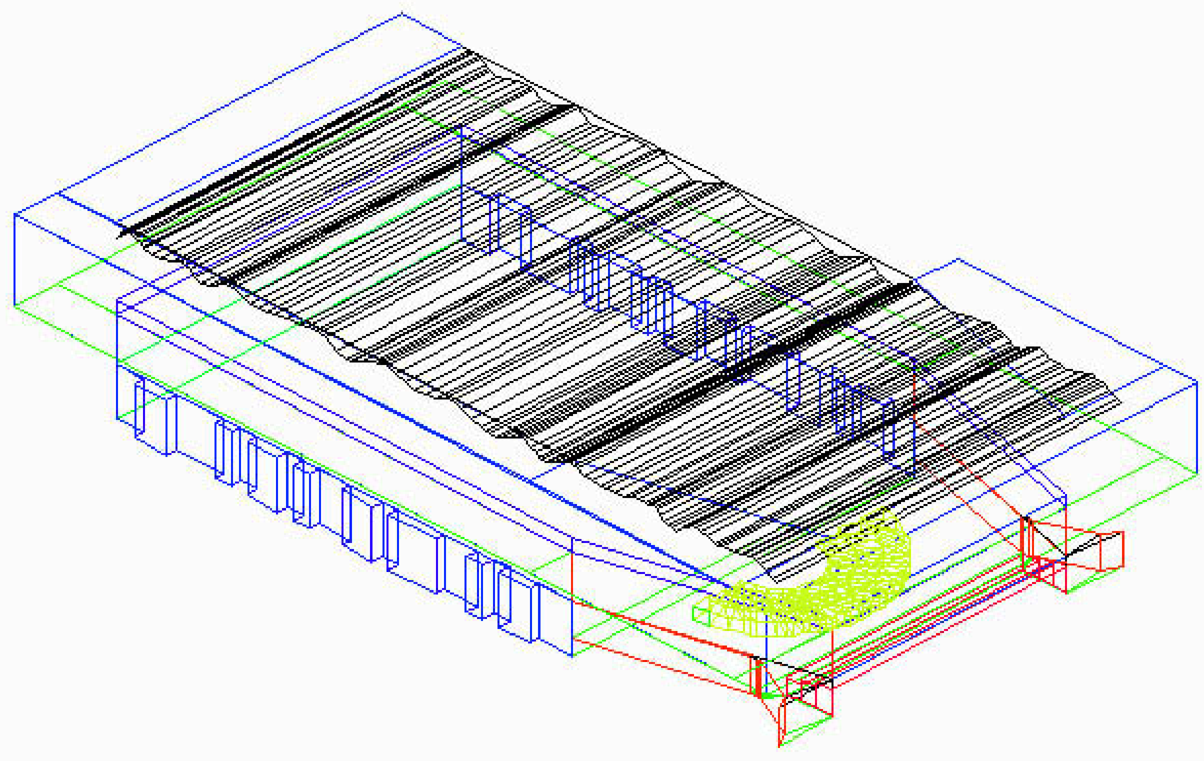


Figure 9: 3D view of computer model

The optimization of the model led to the following decisions:

- Maximum width: 21-m.
- Maximum distance between stage and seat: 33-m.
- Average height: 13-m.
- Acoustical volume: 10500 m^3.

- Diffusive ceiling, hidden rigging, transverse mobile bridge over full length.
- Diffusive and tilted sides.
- Trapezoidal diffusive stage.
- Continuous wood floor on a damped plenum, from stage to last row.
- Flat stalls, except for the last four rows.
- Concert seats, removable.
- Large number of diffusive lateral doors.

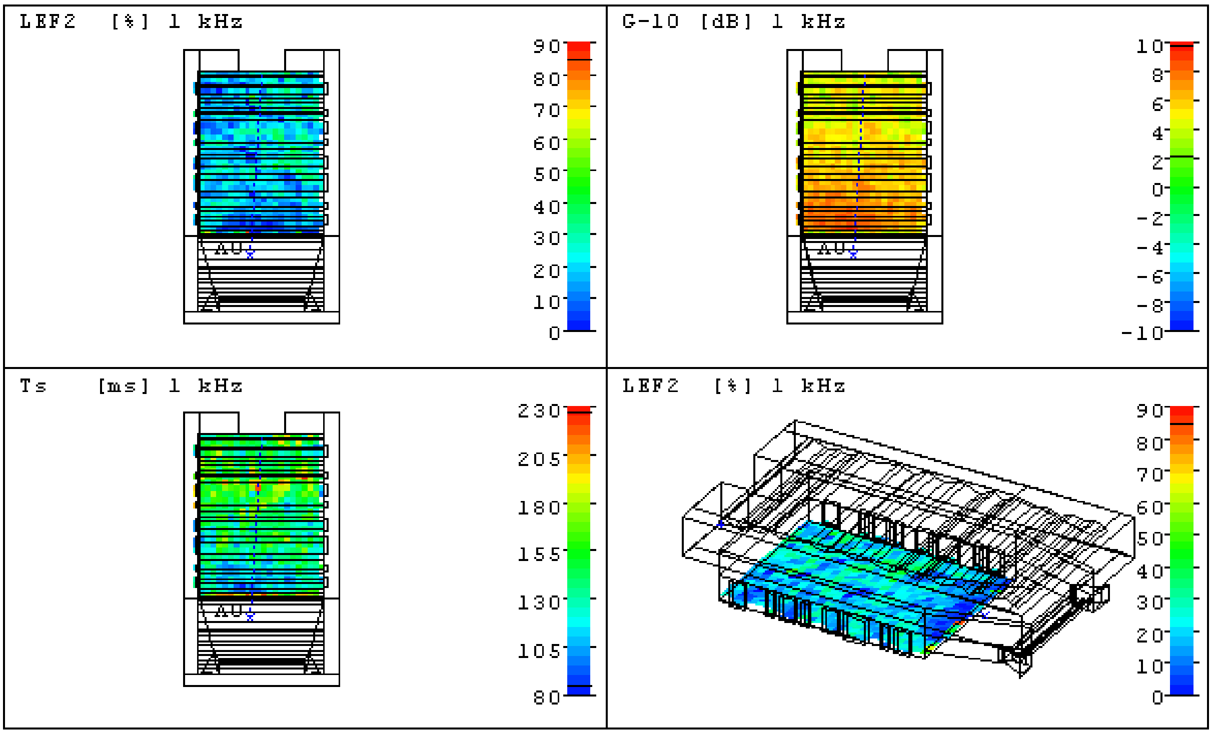


Figure 10: Example of computer output

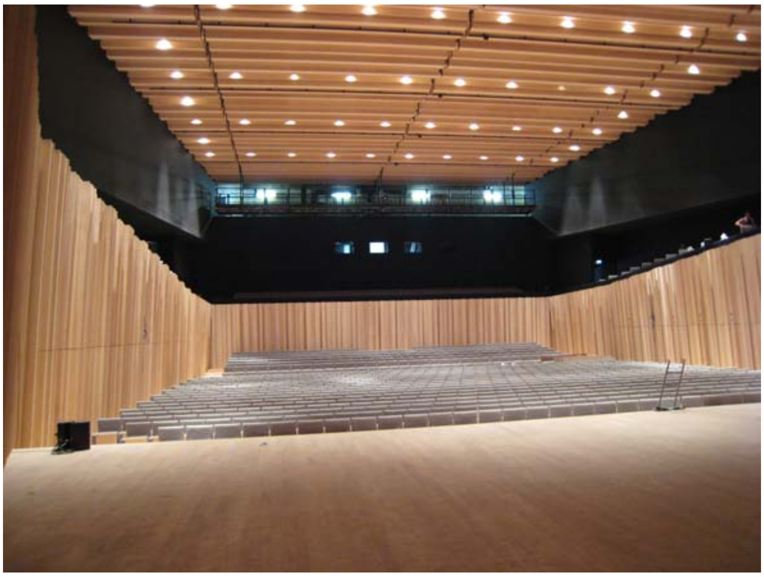


Figure 11: View from stage

To optimize diffusion, to limit absorption and to avoid classical diffuser patterns, experiments were conducted on the design of innovative diffusers. The diffusers are built in wood of various thickness and damping; the lights, riggings, fire detectors and the rails of the movable bridge are inserted in gaps to minimize the acoustical and architectural impact of these metallic components.

Figure 12: Views of stage, ceiling and diffusive doors at end of construction

The lower side walls receive similar diffusers, with different dimensions; the upper side walls are mostly reflective.

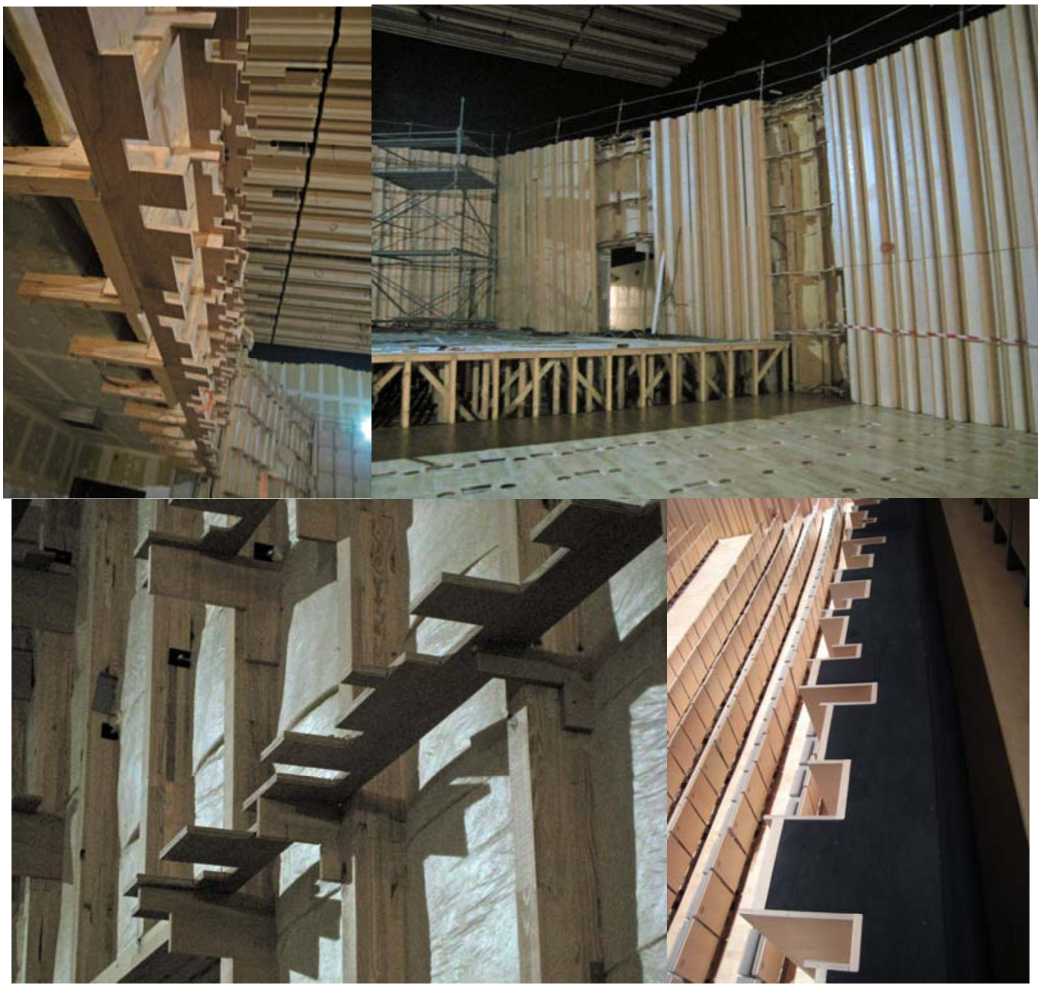


Figure 13: Views of stage and side diffusers (under construction)

The numerous side doors can be opened simultaneously allowing the audience to evacuate the hall at intermission in less than a minute. Since the seats can be removed, stand-up concerts may also be organized; with the doors opened, a large informal concert space can be obtained.

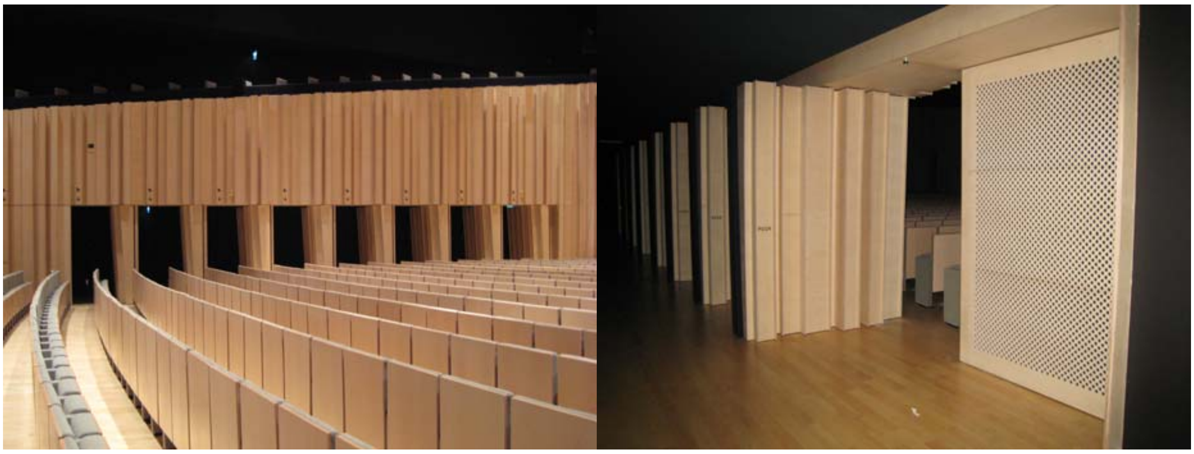


Figure 14: View of sidewall with diffusive doors opened

The shape of the room, the horizontality of the stalls, the multiple door system makes it possible to reduce the room capacity by hanging a transverse curtain or gauze from the movable bridge. Since this bridge can be positioned anywhere, the number of seats can actually vary from 0 to 1021. This same system can be used to transform the concert hall into a genuine recording studio with the orchestra on stage or at the center of the main floor. For variety programmes, additional absorptive curtains can be hung from the ceiling. The following picture shows some results for a 600-seats configuration.

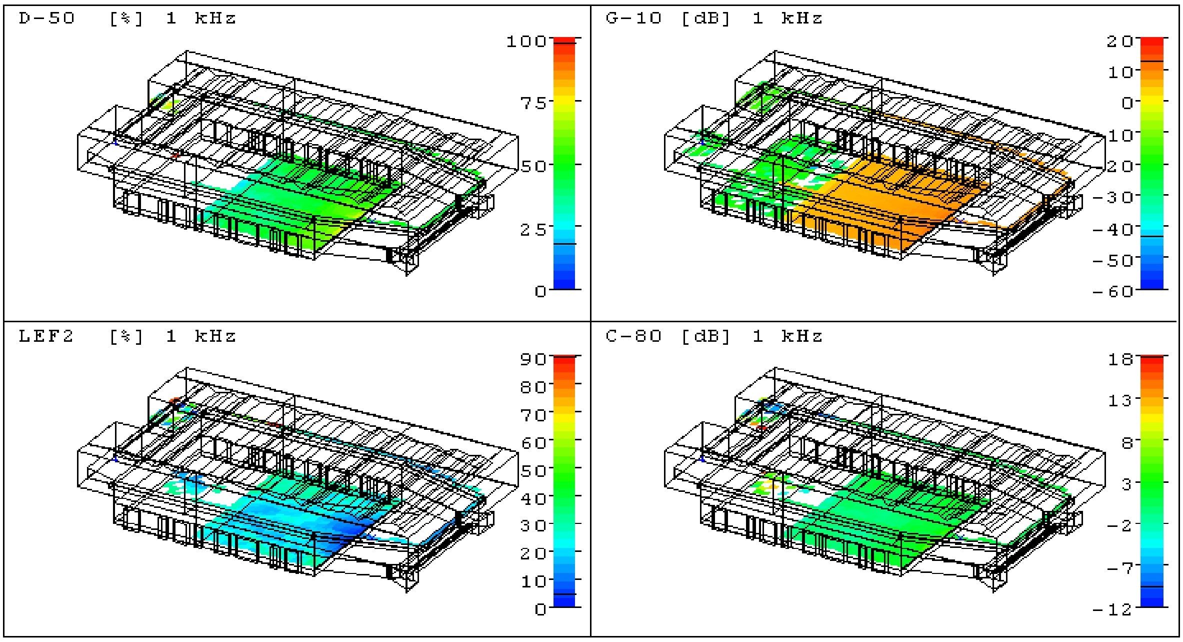


Figure 15: Computer simulation in the chamber music configuration for 600-seats

3.2.1 Objective results for the concert hall

Measurements were performed at the end of the construction phase in the empty hall with about 80% of the seats in place, in the symphony configuration. The objective results are as expected.

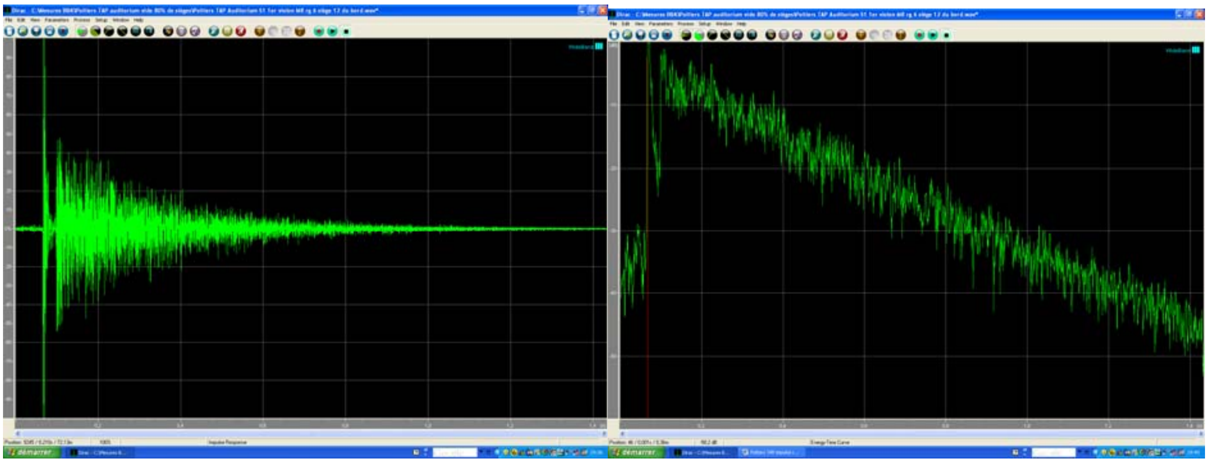


Figure 16: Typical impulse response and energy-time curve

The main results are given below.

Frequency Octave bands (Hz)	125	250	500	1000	2000	4000	8000
EDT [s]	2,205	2,197	2,054	2,015	1,675	1,622	1,329
T20 [s]	1,761	1,705	1,858	2,017	1,910	1,650	1,392
T30 [s]	1,864	1,667	1,990	2,040	1,821	1,664	1,441
RT [s]	1,761	1,667	1,990	2,040	1,910	1,664	1,441
Ts [ms]	184,2	153,8	158,5	150,5	87,7	83,5	83,7
C80 [dB]	-3,53	-2,32	-1,52	-1,54	2,22	2,14	3,35
D50	0,21	0,30	0,26	0,29	0,56	0,53	0,55
MTI	0,40	0,44	0,42	0,41	0,55	0,56	0,56
LF	0,17	0,27	0,33	0,32	0,18	0,25	0,48

Figure 17: Main acoustical results in the symphony configuration

Intelligibility is fair as expected with STI and Rasti at 0,50 and ALC at 11 %. The bass ratio BR is 0,9. The average reverberation time curve is reproduced below with 80 % of the seats in place.

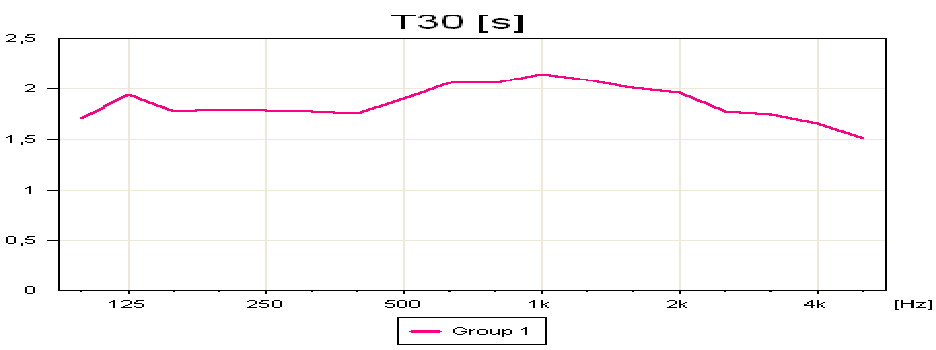


Figure 18: Average reverberation time in the stalls of the empty room from 1st to last row in 1/3rd octave bands

The response and associated parameter values vary little across the room. The next picture shows superposed and shifted responses for the 1st row, in yellow, and the last, in blue.

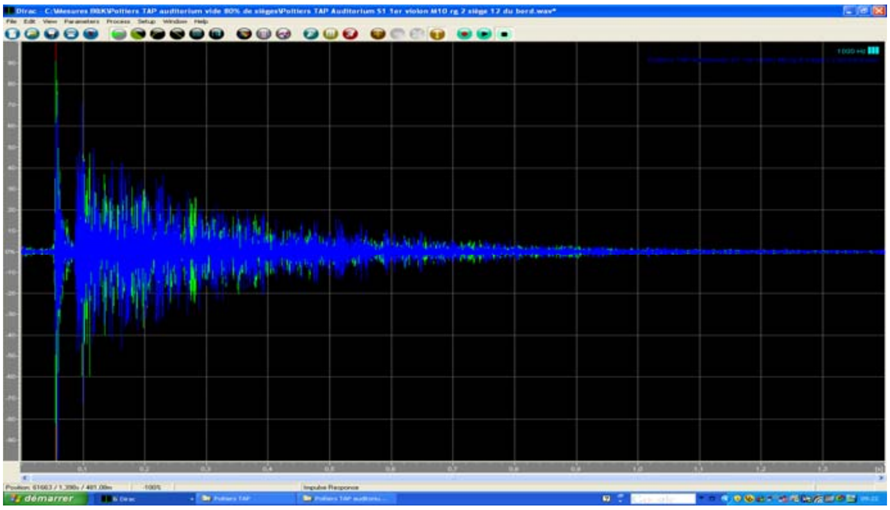


Figure 19: Shifted impulse response overlay for 1st row (yellow) and last row (blue)

3.3 The "concert" foyer

The foyer is designed as an "open" concert hall with the adequate asymmetrical shape, dimensions and materials, a wood floor on a plenum, a continuous absorptive ceiling, minimal rigging equipment. It can therefore be used as a normal foyer but also as an informal performance space.

Figure 20: Foyer (under construction)

3.4 Rehearsal rooms

The building includes a number or rehearsal spaces including a large orchestra and opera rehearsal room.

Since, in the main rehearsal room called "Grand Plateau de Travail" some low cost acoustical flexibility was required so that reverberation time and intelligibility could be adjustable, the plan is slightly asymmetrical, the ceiling is diffusive and two of the side walls receive wood panels, with a 50-cm plenum, that can rotate 360° on a vertical axis.

The thick double-sided panels, reflective on one side, absorptive on the other, can be adjusted by hand to any position.

Reverberation time can be adjusted at will from 1,8 to 1,1 second over a wide frequency range.

Figure 21: Grand Plateau de Travail with panel angles of 0°(reflective), 22,5°, 90°, 180° (absorptive)

4 OPENING PROGRAMME

Open doors multi-disciplinary festivities took place on September 6th 2008. The programme included dance, theatre, classical music with, among others, Philippe Herreweghe and the Orchestre des Champs-Elysées, “contemporary” classical music with Ars Nova, variety, jazz, etc.

This programme was designed as a test for the main performance spaces but also to demonstrate that cultural events of all types could be held throughout the building.

Comments on the acoustics of the concert hall have been very positive. “It is a formidable concert hall” (Ministry of Culture); “Pure and fluid sound without any distortion, always perfectly audible, without excess from high to low frequencies. Excellence in acoustics!” (Sacem); “This exceptional concert hall is the best in France and, most likely, the best in Europe; I wish we could have such concert halls in Belgium and elsewhere in Europe” (Philippe Herreweghe); “Unparalleled acoustics” (Agence France Presse).

The rich and diversified music programs will moderate or confirm these early assessments.