19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

"LE GRAND THEATRE DE PROVENCE" : THE AIX-EN-PROVENCE OPERA HOUSE ACOUSTICS

PACS: 43.55.Fw

Commins, Daniel
commins acoustics workshop, 15 rue Laurence Savart, F-75020 Paris;
d.commins@comminsacoustics.com

ABSTRACT

A new opera house has been inaugurated in June 2007 in Aix-en-Provence in the South-East of France. The 1380-seat hall is to be used mostly by the world-famous Festival d'Aix-en-Provence for operas and symphonic concerts. Off season, it will be used for communities around as a cultural centre for performances of various types, from jazz to dance.

Acoustics has driven the design. The team of Vittorio Gregotti, architect, has translated the acoustical requirements into a compact contemporary version of the classical Italian opera house: a quasi-circular shape with three balconies, a volume of 10300 m^3, a maximum distance of 32-m between edge of stage and last balcony row, an excellent visibility of the stage from all seats, wooden floors on sleepers, tuned wooden walls and a variable capacity orchestra pit. The 20.000-ton building is laid on springs to filter vibrations from the nearby railway tracks and heavily travelled road.

The main challenge consisted in designing for musicality and clarity for the opera configuration and to be able to transform the room into a genuine concert hall: a light orchestra shell, weighing about 6 kg/m^2, is installed on stage or removed in less than two hours.

This hall was inaugurated on 30 June 2007 by a concert of the Berlin Philharmonic Orchestra, under Sir Simon Rattle. Subjective and objective results are presented.

A MAJOR OPERA HOUSE IN THE SOUTH OF FRANCE

Aix-en-Provence is a major player in the opera circuit with its famous "Festival d'Art Lyrique". A new opera house, inaugurated in 2007, completes the available facilities. However, the use of the building is broader: it is also a concert hall and it must be able to host other types of events and to serve the surrounding community and even the Provence region.

The main function of the hall is the performance of operas. Since the size capacity of 1380-seats is quite reasonable, the use of a full orchestra shell transforms the room into a genuine concert hall. For other uses, a modest absorption system has been introduced.

THE BRIEF

A number of essential parameters were specified in the brief [1]. It defined that the main hall would be mainly used for operas and symphonic concerts; it should also be able to host jazz, variety, recorded sound and dance. The length of the 900-seat stalls is limited to 25-m. The width of the stage opening is 16-m. The first rows can be transformed into a genuine orchestra pit for a full orchestra.

For concerts, a full orchestra shell transforms the room into a genuine concert hall. The orchestra shell is to be designed for good ensemble conditions.

The main goals are a harmonious musical sound, good balance and adequate clarity for lyrics.

In addition to the main opera house, the building has a large rehearsal hall, with moderate acoustic variability, for orchestras, choirs, voice and dance. Several music studios, from small to large are available for the resident orchestra.

Since the building lies near a railway track and is surrounded by a major city road, it is necessary to protect it against urban noise as well as against railway vibrations.

THE DESIGN PROCESS

The Aix-en-Provence opera house, designed by Gregotti Associati International, is the result of an international competition between major architectural firms. The steps of the design process are summarized in the following table.

Phase	Options Action	Method	Validation	Tools
Competition	Volume, shape, materials, short note	Simple calculations, computer model	Morphology, materials, main acoustic parameters	Equations, graphic analysis, rough computer model
Preliminary design	Detailed specifications, acoustic brief	Computer model tests	Results for TR, C80, LE, Ts, D50, impact noise levels, insulation, radiated noise, acceleration levels	Algorithms, computer model
Detailed design	Final specifications, detailed acoustic note	Detailed computer model tests	Final prediction of TR, C80, LE, Ts, D50, impact noise levels, insulation, radiated noise, acceleration levels.	Algorithms, detailed computer model
Project and construction specifications	Check, adjust details, specific acoustical means	Quality control	Plans and details	Data on materials and systems
Follow up and commissioning	Analysis of execution documents and modifications	Meetings, on site verifications, measurements	Objective acoustic and vibration criteria	Acoustics and vibration measurement and analysis systems

Design principles of the opera house

Since the requirements of the programme were adequate, they were preserved. The following illustrations show in sections and plan the main hall.

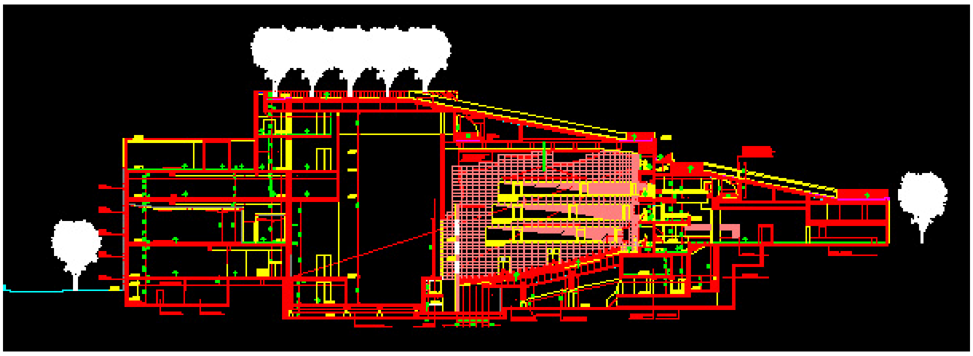

Figure 1.-Longitudinal cross-section of the “Grand Théâtre de Provence”

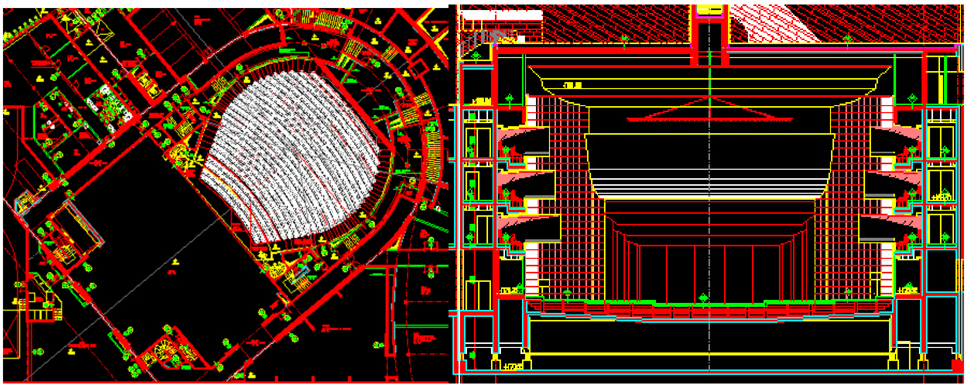

Figure 2. - Plan and transverse section of the “Grand Théâtre de Provence”

Because of its efficient shape, the room is intimate; the furthest distance between last row and stage is 32-m for the highest balcony seat and 26-m for the stalls. Note that there are only two rows of seats in the balconies.

The main design options are the following:

- Acoustically driven project.
- Intimacy, short distances, diffusion, warmth, favourable relationship between pit and stage, between pit and audience, between stage and audience.
- Volume from stage frame: 10300 m^3 (Opera volume per person: 7,5 m3).
- Total volume with orchestra shell: 11600 m^3 (Symphony volume per person: 8,4 m3).
- Direct lines of sight for unobstructed direct sound for all seats.
- Efficient lateral and vertical reflections.
- Diffracting balconies.
- Peripheral technical gallery around top of hall.
- Wood floor on sleepers, wood side panels with tuned acoustic response, plaster ceiling, concert hall seats with 10-mm wood backs and 10-mm perforated wood underseats.
- Partial fixed absorption on stage.
- Ceiling shape: broken inverted lens with integration of technical services, large reflector above pit.
- Wood construction of orchestra pit, wooden pit floor on sleepers, diffusive back wall.
- Peripheral curtain for jazz, songs and similar activities.
- Vibration insulation, 20000-ton building suspended on damped springs for 7-Hz cut-off frequency; seismic-proof construction.
- Total noise insulation of the hall, multiple plasterboard boxes, large insulating stage doors, floating floors.
- Classical noise and vibration control technology throughout the building for NR 20 in the main house: low velocity HVAC (intake under seats), quiet stage equipment, suspended equipment, etc. Low noise emission in the environment.

The orchestra shell

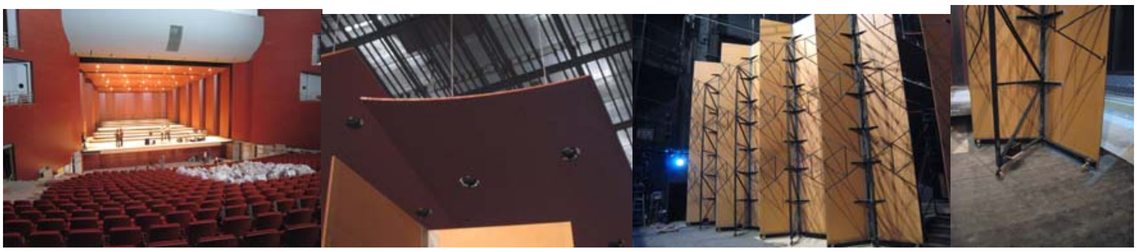

Figure 3.-The orchestra shell, a ceiling panel, light structure, wheel system

The main role of the orchestra shell is to transform the opera house into a genuine concert hall for recitals, "Mozart" style orchestras, symphony orchestras with and without choir. Strict requirements for the orchestra shell were applied: efficient design for audience and musicians, light weight with proper acoustic response (6kg/m²), aesthetic extension of the hall, short transformation time, easy and compact storage, and integrated lights. The side walls are partially open to provide escape routes and for controlled coupling with the damped stage tower.

The multi-layered composite panels, defined to match the expected acoustic response, have the following characteristics : fire resistant and free of toxic gas emissions composite core, 3 directional glass cloth layers epoxied on one side, 2 directional layers on the other side, non toxic epoxy, panel colour matched to the colour of the hall. The nature, dynamic response, direction and density of each component are carefully selected to match the expected overall acoustic response. The vertical panels are self-standing. The material is temperature resistant up to 100°C to allow integration of low-temperature lights in the ceiling.

The total area of the shell is 502 m² for a weight of 3012 kg. Time for assembly, including the wood orchestra podiums, is less than 2 hours; dismantling takes less that 1,5 hours.

Predicted results at the design stage

A computer model was built at the competition stage and developed during design. The clear results made unnecessary the construction of the 1/16 scale model, originally planned.

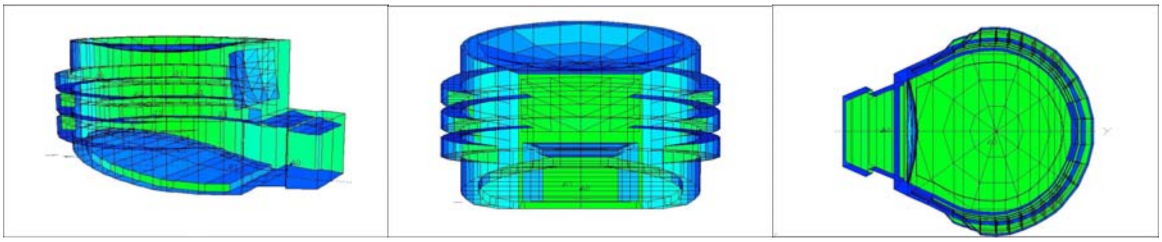

Figure 4.-Views of computer model: 3-D, transverse and in plan

Opera configuration

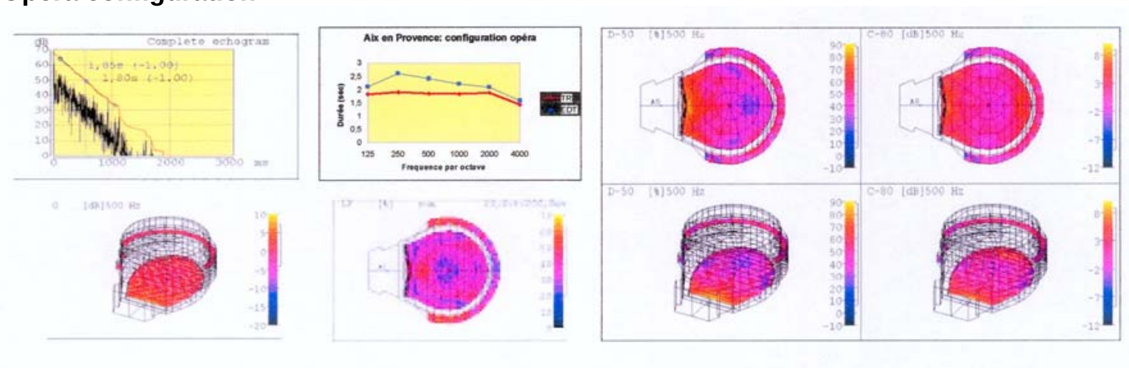

Figure 5.-Examples of predicted results in the opera configuration

Paramètre	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Programme ou objectif
Durée de réverbération TR_{Eyring} en s.	1,83	1,91	1,86	1,85	1,88	1,44	1.8
Définition D_{50} %	29.9	33.2	43.7	45.1	45.5	42.8	40
Clarté C_{80} dB	0.12	0.15	1.4	1.6	1.8	3.1	-2 à +2
Efficacité latérale LEF %	30.3	30.2	36.8	27.5	33.9	34.4	30
Force sonore G_{10} dB	3.1	1.93	1.85	1.8	1.8	1.5	0 à 4
EDT s.	2.12	2.61	2.42	2.22	2.09	1.59	> TR
STI (intelligibilité) en %				50 à 64			> 50
Temps central T_s			70 à 100	75 à 120			< 140 ms

Figure 6.-Example of calculated values in the opera configuration

Symphony configuration

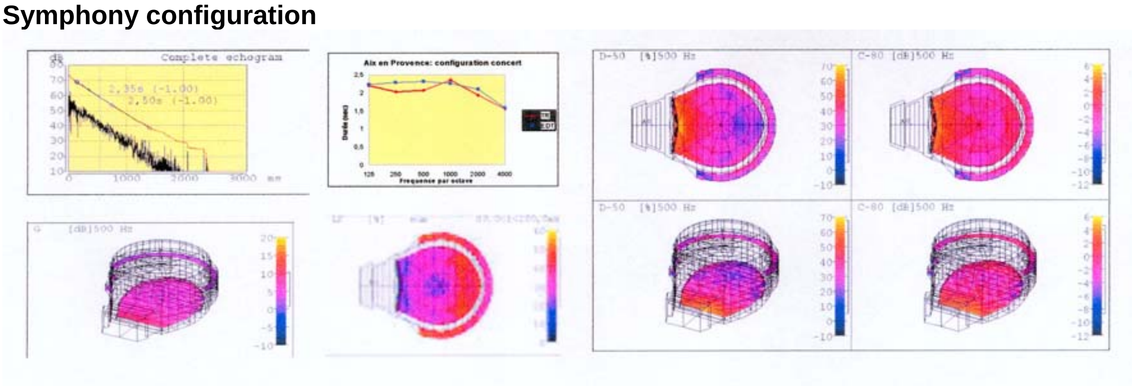

Figure 7.-Examples of predicted results in the symphony configuration

Paramètre	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Programme ou objectif
Durée de réverbération TR_{Eyring} en s.	2.20	2.03	2.07	2.35	1.93	1.56	2.0
Définition D_{50} %	25.3	29.2	37.4	39.2	37.4	32.8	30
Clarté C_{80} dB	-1.1	-0.8	0.5	0.9	1.3	2.2	-2 à +2
Efficacité latérale LEF %	18.2	17.3	20.1	22.3	21.5	24.8	20
Force sonore G_{10} dB	5.2	4.28	5.6	4.82	4.96	4.3	0 à 6
EDT s.	2.23	2.28	2.31	2.26	2.1	1.58	> TR
Temps central T_s			80 à 140	87 à 150			< 140 ms

Figure 8.-Example of calculated results in the symphony configuration

EXTERIOR AND INTERIOR ARCHITECTURE

Figure 9.-Outside representations of the “Grand Théâtre de Provence” and views towards stage and towards balconies in the symphony configuration

ACOUSTICAL RESULTS

Preliminary acoustical measurements have been performed in the empty hall a few days before construction was completed with about 30% of the seats and some other absorbent elements missing [2]. The results should not be considered final but they provide trends.

When corrected for the missing components, the results in the symphony configuration for RT, EDT, D_{50}, C_{80}, LEF, G and T_s are close to the targets. Final measurements will be performed in the finished hall for validation.

The objective of associating good clarity and intelligibility to a long reverberation time has been met.

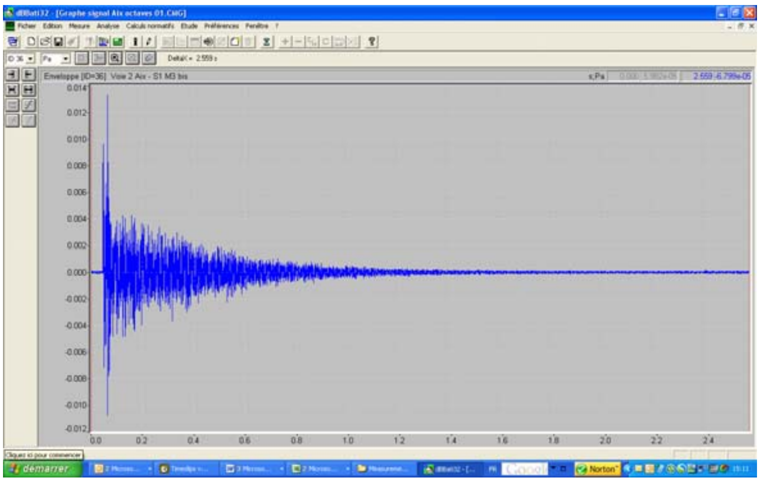

Figure 10.-Typical impulse response showing strong early reflections from the pit reflector

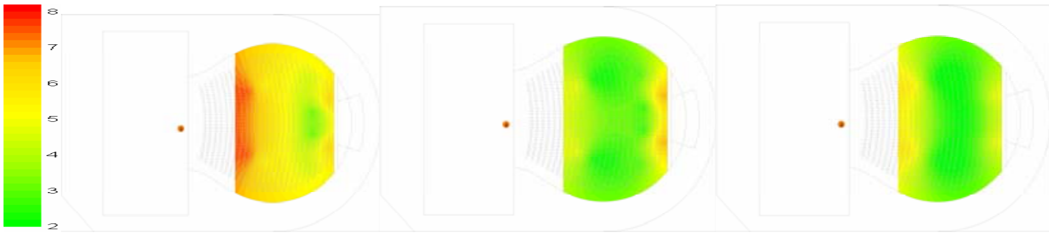

Figure 11.-Maps of strength at 500, 1000 and 2000 Hz in the symphony configuration

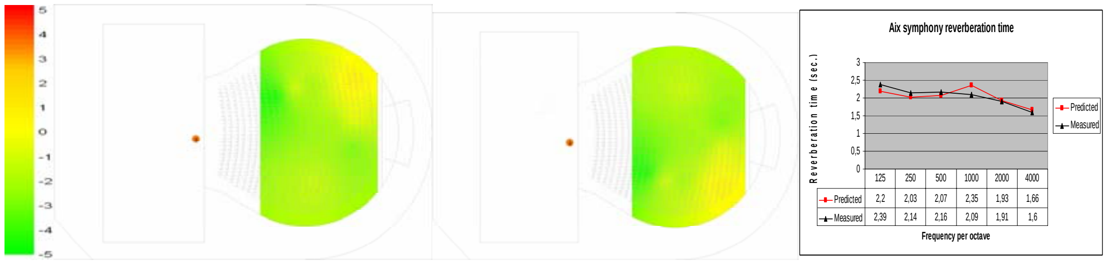

Figure 12.-Maps of clarity in the symphony configuration and corrected reverberation curve

Rehearsal rooms and music studios

A large and a small rehearsal room are included in the building as well as six studios for the resident orchestra. Their shapes are asymmetrical; a number of diffusive and of absorptive movable curtains are included. They are all highly insulated and have a damped wooden floor on sleepers and on floating slabs. The large 2000-m3 rehearsal room can accommodate a full symphony orchestra and choir, up to two-hundred musicians and singers.

Figure 13.-View of diffusers in the large rehearsal room, under construction, and in a studio

Vibration isolation

Since the building lies a few meters away from railway tracks on one side and from a heavily travelled road on the other, the whole building has been suspended on 350 spring boxes with a cut-off frequency of 8 Hz and a deflection of the order of 12 to 16-mm. Since the area is seismic, the same system integrates earthquake protection devices. Most of the noisy or vibration generating equipment is installed in the technical space under the spring boxes.

Figure 14.-Views of spring systems under the 20000-ton opera house

References: [1] F. Lefèvre, G.-L. Rouch: Salle de Spectacle du Pays d'Aix, competition brief (2002).
[2] D.Commins, A. Farina, L. Conti, L. Rizzi, A. Rosati: Grand Théâtre de Provence preliminary acoustical measurements, May 2007.