THE ACOUSTICAL SHELL
OF THE "NUOVO TEATRO COMUNALE" IN CAGLIARI

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INTRODUCTION

Often an opera house is used for performances very different from operas, such as symphonic concerts. In these cases, the orchestra is not placed inside the pit, but on the stage. The orchestra pit is left unused, or it is often elevated to the same height as the stage floor, thus becoming a continuation of the proscenium.

Usually the acoustics of an opera house is not well suited to ensemble performances with the orchestra on the stage: the reverberation time is too low, and the clarity is high for sources located on the stage, thanks to strong specular early reflections produced by the side walls of the proscenium. These effects are useful during operas to reinforce the voice of the singer against the power of the orchestra. In addition, opera houses have large stages, to allow many sceneries to be stored. When the orchestra is located in this space (usually greater than the audience room itself), which is not filled with sceneries or other sound absorbing materials, the musicians are actually playing in a very reverberant space, poorly coupled with the hall through the proscenium.

In such cases an acoustic shell is required, which encloses the orchestra on the stage, separates the two acoustic fields and gives musicians a more confortable acoustic environment, properly coupled with the room. Furthermore, reflections inside the shell and diffusion over its walls produce a more blended sound coming to the audience, while also increasing the capability of musicians to listen to each other.

In this paper a typical case is presented: the new opera house in Cagliari was finished in 1993, but it was impossible to open it with an opera, due to the lack of funds required to complete the stage equipment. So it was decided to give a series of symphonic concerts, conducted by Riccardo Muti: thus a new modular acoustic shell was designed and built, resulting in a very noticeable change in the acoustics of the theatre, which made it possible to satisfy the musicians, the conductor and the audience.

The authors explain first the design criteria adopted for the shell, and then present the experimental results obtained before and after the installation of the enclosure.

ACOUSTIC DESIGN OF THE ROOM AND OF THE ACOUSTIC SHELL

The Nuovo Teatro Comunale in Cagliari was built over more than 20 years, during which the original project was changed substantially. When the acoustic consultants were hired, they introduced modifications to the shape of the side walls and to the furnishing material, with the aim of producing an opera hall characterised (as required) by high clarity and intelligibility, but with a reverberation time not as low as many other Italian historical opera houses, which are nowadays very “dead” due to the superposition throughout the centuries of thick carpets, upholstered seats, fabric, etc. [1,2].

The experimental measurements taken after completing the room showed that the project’s aims were perfectly reached. Nevertheless, the completely empty stage was characterised by an extremely high reverberation time (more than 5 s !), and thus it was necessary to exclude it from the hall’s acoustics.

The first requirement for the acoustic shell was a perfectly tight sound insulation from its surroundings, so a heavy wood panel was chosen to build both the lateral walls and the ceiling.

Secondly, the shell had to be completely modular and easily mountable, so the panels were fixed to steel towers, moving on lockable wheels, each of which has its own mechanism to lift up the panels, which are usually packaged one inside the other. Also the steel towers can be packaged one inside the other, thus reducing the storage space required. The ceiling panels are fixed to modular reticular beams, then lifted up through cables, and placed over the top of the lateral towers. They also include a sophisticated lighting system.

The surface of the panels is not flat everywhere: each panel is a box closed on five faces, some of them mounted with the open face looking out the chamber, and others in. This way the overall surface is uneven, with cavities or extrusions of different depth.

The lateral walls of the acoustic shell are properly sloped, in such a way that a certain amount of sound energy is reflected toward the audience, particularly in the central area of the main floor, where the fan-shaped plant gives no useful reflections coming from the lateral walls of the room. The ceiling has a slight average slope, obtained with a succession of horizontal panels, as its aim is not to redirect energy towards the audience, but to enable the musicians to hear each other: to make this possible, a proper height of about 8 m was chosen, as this was proved to be optimum in previous research [3].

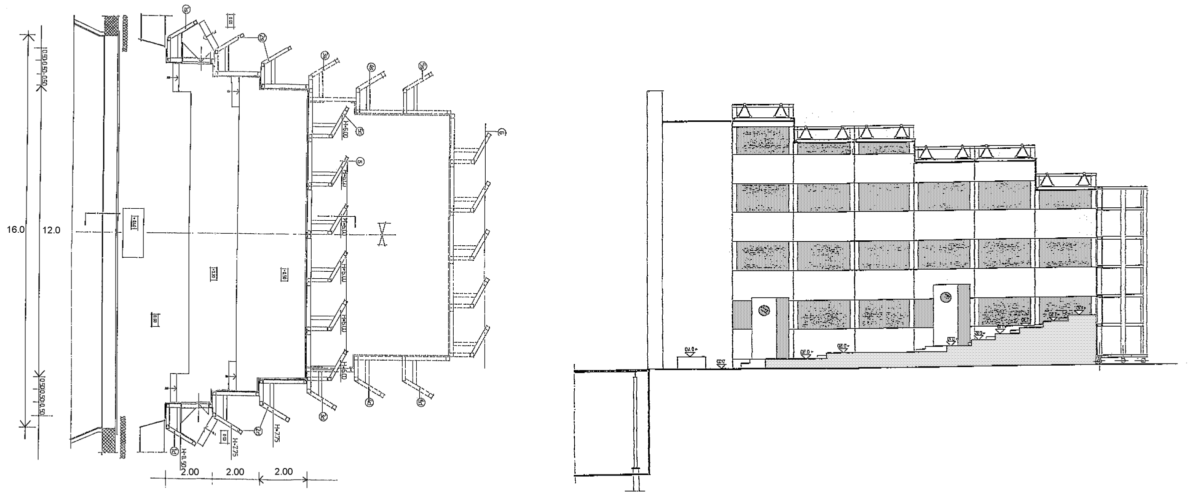

Fig. 1 - Plan and vertical section of the acoustic shell

EXPERIMENTAL RESULTS

Two exhaustive measurement sessions took place before and after the installation of the acoustic shell. The experimental setup was constituted by a portable PC fitted with a MLSSA acquisition board, a power amplifier, an omnidirectional loudspeaker, a dummy head with binaural microphones, a DAT recorder and a real-time octave band analyser. The basic quantities measured are 64-k points long Impulse Responses, from which the acoustic parameters are computed accordingly to ISO-CD 3382.

Figure 2 shows the reverberation times before and after the installation of the acoustic shell.

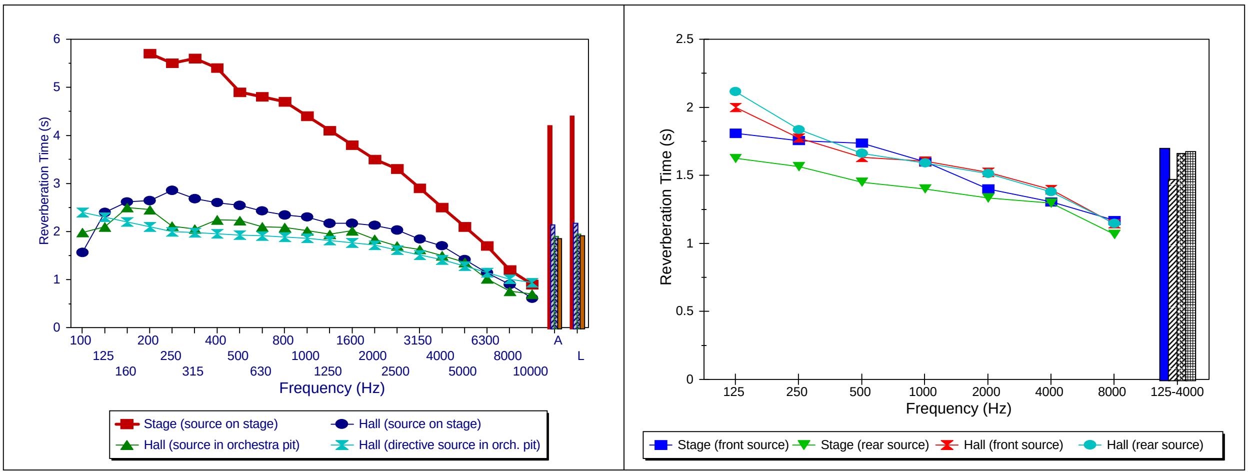

Fig. 2 - Reverberation times before (left) and after the installation of the acoustic shell

It can be seen how this enclosure removes the tremendous effect of the empty stage, giving a consistent reverberation both for listeners and performers, perfectly suitable for symphonic music (considering that the hall was empty).

Also the other objective acoustic criteria show the effect of the shell; the table 1 summarises the results for 5 widely used parameters.

Table 1 - Main acoustic parameters (overall values 125-4000 Hz)

		Source in the orchestra pit, no acoustic shell					Source on stage, without acoustic shell					Source on stage, with acoustic shell				
Point	**Location**	**C50**	**C80**	**D50**	**ts**	**EDT**	**C50**	**C80**	**D50**	**ts**	**EDT**	**C50**	**C80**	**D50**	**ts**	**EDT**
5L	**Stall**	0.3	2.7	48	97	1.55	5.2	6.2	76	66	2.14	2.0	3.6	50	93	1.88
5R	**Stall**	-1.4	1.9	39	110	1.56	2.6	4.0	64	89	2.31	1.7	3.3	49	97	1.83
7L	**Stall**	-0.7	1.8	45	111	1.76	2.7	4.0	65	97	2.13	-2.3	1.1	36	112	1.70
7R	**Stall**	2.1	4.0	60	91	1.62	2.6	4.2	64	95	2.12	-0.6	2.1	46	102	1.74
9L	**Stall**	2.7	4.5	63	79	1.42	6.1	7.3	78	69	1.30	2.8	3.9	62	84	1.91
9R	**Stall**	0.6	3.2	52	93	1.46	5.5	6.4	73	75	1.88	1.1	2.3	51	100	2.03
16L	**1st balcony**	0.3	2.0	50	107	1.70	3.8	5.3	64	84	1.97	5.1	6.5	72	56	1.40
16R	**1st balcony**	1.4	4.1	57	89	1.45	2.6	4.4	62	87	1.93	4.6	6.2	70	58	1.35
19L	**1st balcony**	1.7	4.7	58	82	1.15	5.4	6.9	77	66	1.27	3.1	5.1	61	72	1.30
19R	**1st balcony**	0.9	3.7	54	88	1.27	3.7	5.1	69	76	1.45	-0.1	2.8	47	88	1.34
24L	**2nd balcony**	0.3	2.3	51	104	1.72	0.6	2.0	54	108	1.95	2.8	5.8	64	63	1.14
24R	**2nd balcony**	0.7	2.5	54	102	1.70	0.0	1.5	50	112	1.93	1.5	4.2	56	77	1.31

The acoustic field on the stage (which is relevant for musicians) was fundamentally changed after the installation of the acoustic shell, as it can easily be seen from the comparison of the energy impulse responses measured without and with the acoustic shell (fig. 3). Without the acoustic shell the reverberant queue is very long, and the first reflections are comparatively weak, whereas after the shell has been installed the reverberation is reduced, while strong early reflections appear.

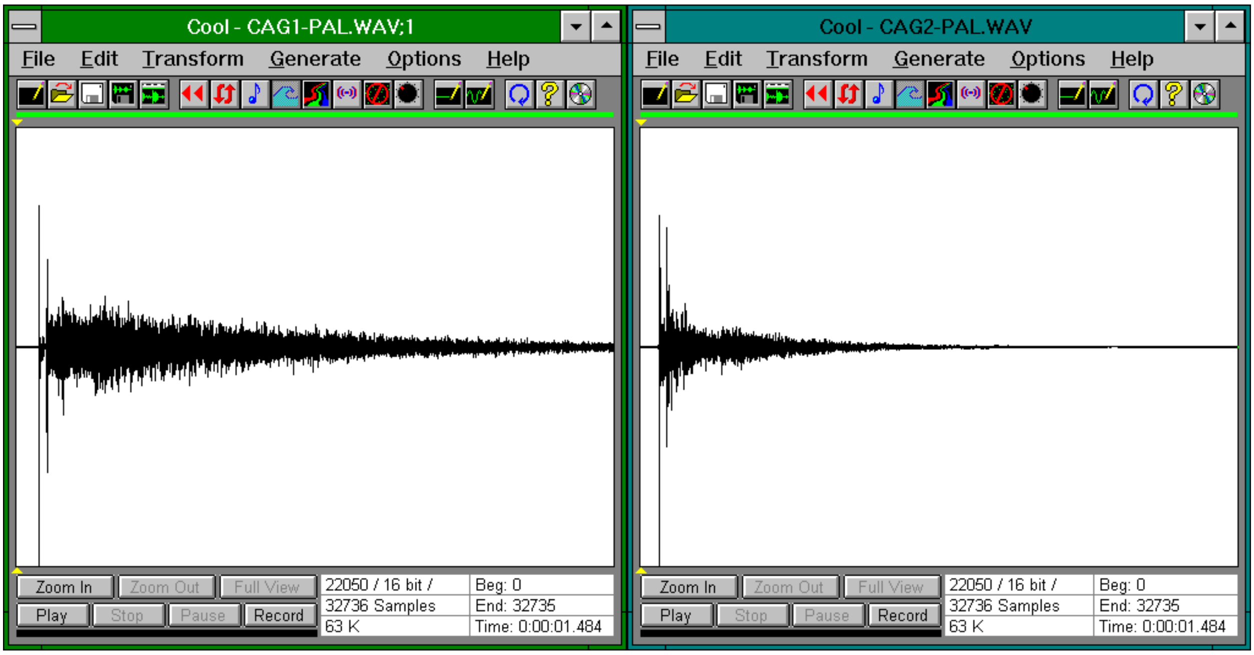

Fig. 3 - Comparison of Impulse Responses on the stage without (left) and with acoustic shell

CONCLUSIONS

Both the experimental results and the judgements expressed by musicians and listeners after the first concert show that the acoustic shell was capable of converting the opera house into a good concert hall. This was possible by carefully designing the acoustic shell, but it must be noted that such good results could not have been achieved if the room had initially been too dead, as is the case in many other Italian opera houses.

The acoustic shell can be successful in excluding the large volume of the stage from the room, making it possible for the musicians to “feel” the acoustics of the room and not that of the stage. Furthermore, a properly designed acoustic shell can blend together the sound of various instruments, with benefits both for the listeners and for musician’s capability of playing together, by properly redirecting the reflected waves in areas where they are needed.

However, the acoustic shell has only limited benefits on the reverberant field inside the audience room. In any case it is not capable of increasing much the reverberation time (if it is too low), and thus for historical theatres the only suggestion is to properly restore the absorbing surfaces, the seats, the floors and the fabrics to their original state, removing any sound absorbing object introduced during the last century [2]. When the room has reached a reverberation time high enough to sustain symphonic music, a properly designed acoustic shell makes it possible to place the orchestra on the stage, with acoustical results very similar to those obtained in the most famous concert halls.

REFERENCES

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