IMPROVEMENTS IN THE ACOUSTICS OPTIMIZATION OF THE STREHLER THEATRE

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ABSTRACT

When the Strehler theatre was planned, its performances from the acoustics point of view have not been taken in the right account. As a consequence, the theatre has now an appreciable visual impact but a poor acoustics.
Thanks to the first measurements we have been able to ascribe the main reasons of the lack of good acoustics to the shape and the materials of the hall. Therefore we first suggested some simple operations to improve the acoustics of the theatre. The results have validated our simulation model and we have been able to identify the definitive structural operations for a good listening of music and drama as described in this paper.

THE STREHLER THEATRE

In 1997 a new theatre was opened in Milano: the Strehler theatre. The theatre was originally planned to host drama only, but later on the management decided to perform musical events too. As the lack of good acoustics came out very soon, the management ask the Acoustic Laboratory of the Milano - Bicocca University to study the problem and to suggest some solution.
Regarding the acoustical characteristics, the Strehler theatre is essentially made of three connected sections: the stage, the stalls, and the balcony.
Of the three sections the stage has the simplest form: it is shaped after a regular parallelepiped 25 m wide, 16 m long and 24 m high. The only relevant acoustical characteristics is the presence of a false ceiling made of wood rules 10 cm wide and 0.5 cm apart.
The base shape of the stalls is an irregular eight sided polygon, with equal paired sides with respect to the symmetry axis. The length of the paired sides are: 18.5 m, 6.5 m, 11.5 m, and 3.5 m respectively. The slope of the stalls places each seat 8 cm higher than the preceding one thus allowing, for all the audience, both a full vision and a good reception of the direct sound originating at the stage. The stalls consist of 550 seats in 16 rows.
The gallery, of the same form of the stalls, but with a greater slope, is placed 3 m above the latter. This feature allows the reception of the direct sound from the stage but also a short distance and an acceptable sound intensity. The gallery consists of 404 seats in 8 rows.
The theatre, specially designed for drama, turned out to be unsuitable for musical programs but soon displayed some limitation even for drama itself.

FIELD MEASUREMENTS

A sine sweep function was used as test signal for the present measurements. A digitized signal guarantees measurement repeatability and a high S/N ratio; moreover a sine sweep allows the correction of small system non-linearity which would appear, for example, in case of a MLS technique. The sine sweep signal was generated by the software for musical editing Cool Edit Pro© with Aurora© acoustic plug-in. The signal was sent from the computer (HP Omnibook 4150) through a RF transmitter-receiver to a power audio amplifier; an omnidirectional dodecaedric diffuser (Bruel & Kjeaer – model 4296) acted as sound source.
The acoustic field was sampled with a phonometer (Bruel & Kjaer – model 2260) linked to the same computer and subsequently analyzed with Cool Edit Pro© and Aurora©.
The perfect symmetry of the hall allowed the performing of measurements only in one half of the theatre: in order to quantify the acoustical properties of the hall 10 points in the stalls and 8 points in the gallery were chosen. The purpose of the measurements was the characterization of the hall to check the results of a ray-tracing software (Ramsete©). This program allows the simulation of a number of acoustical parameters using a reconstruction of the hall in a CAD format. This kind of simulation is of great interest because it models the acoustical impact of possible changes of the hall before the actual modifications. After having measured and computed the values of several parameters we have compared them to the results obtained by Ramsete©.

<u>Clarity</u>

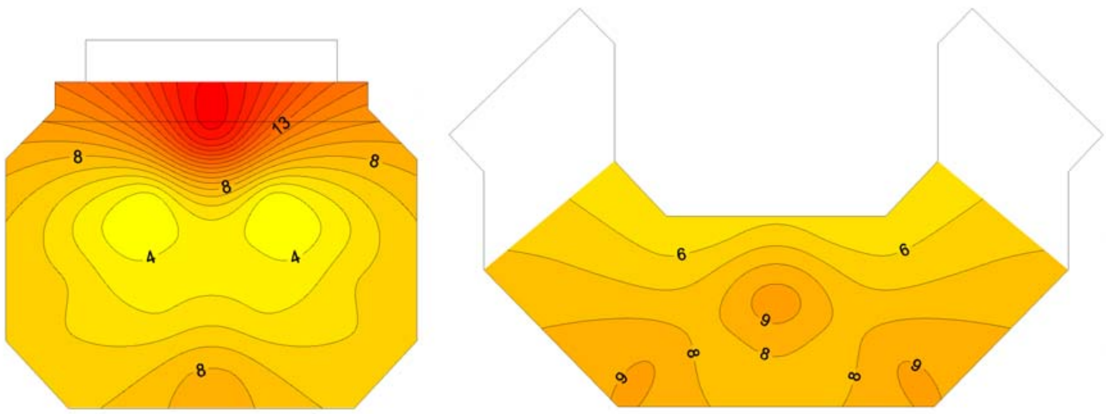

Figure 1. Plot of C_{80} distribution – experimental data.

It can be seen that in the middle of the stalls, C_{80} displays an area characterized by low values and two symmetrical minima. The rest of the stalls do not present particular problems for drama reception and the same is true for the gallery.

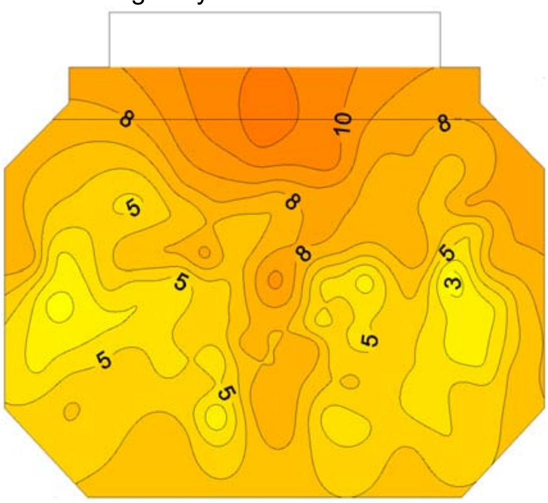

Figure 2. Plot of C_{80} distribution – simulation.

The simulation of the gallery was not possible due to a limitation of the program: the software is able to reproduce maps only if the virtual receivers are all at the same height and this is not the case of the gallery characterized by an enhanced slope.
It can be seen that the correspondence between experimental and simulated values is almost perfect. In particular the two maps display the same trend and the same two minima.

Definition

Same considerations are for the D50, where the experimental data show the trend shown in Figure 3.

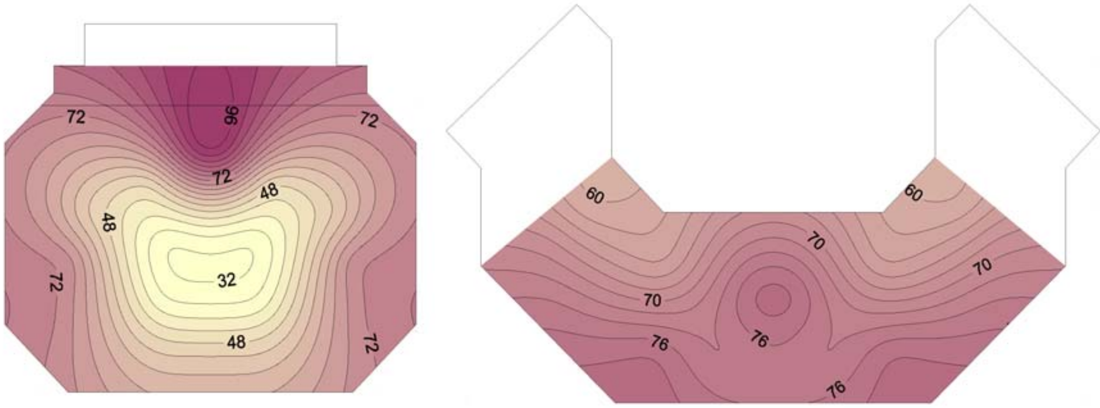

Figure 3. Distribution of D50 - experimental data.

The map confirms that, because of the excessive width of the hall (30 m), in the centre of the stalls the first reflections are not sufficient to get right values of Clarity and Definition for a good listening of drama. Moreover the shape of the boccascena and of the side walls near it are not suitable for sending the sound to the centre of the stalls.
For this parameter the Ramsete simulations provide a very good similarity:

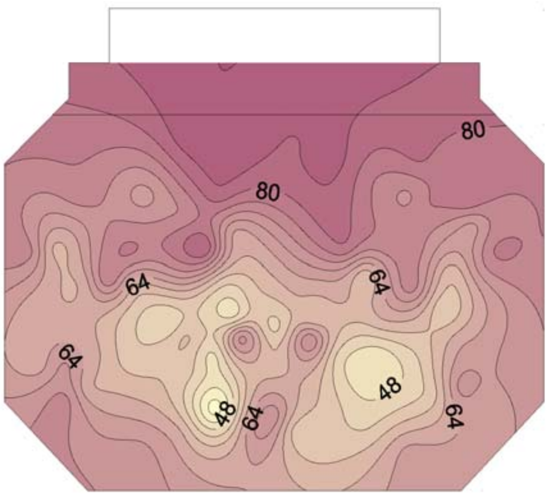

Figure 4. Distribution of D50 – simulation.

Initial Time Delay Gap

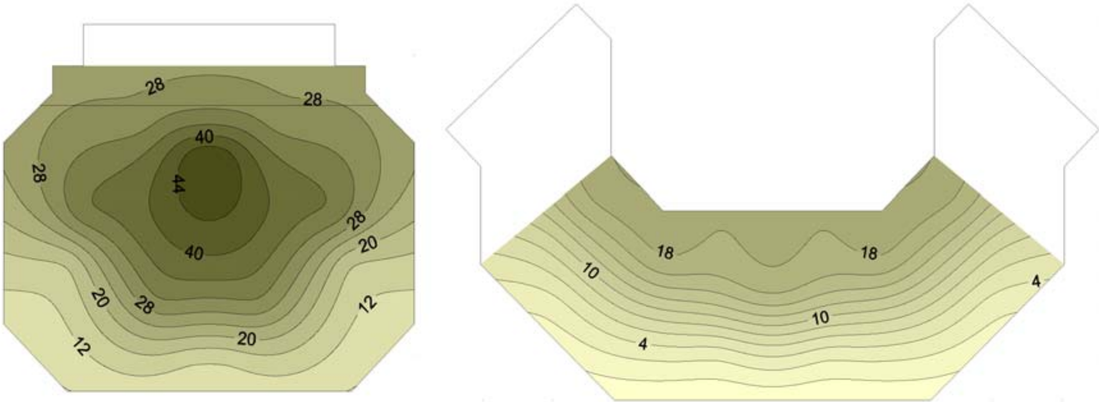

Figure 5. Distribution of ITDG - experimental data.

As displayed in Figure 5 the stalls show unacceptable ITDG values: only in the zone near to the walls there are values under 25 ms. Conversely the whole balcony, which benefits from the closeness of the ceiling, shows good values of the ITDG.

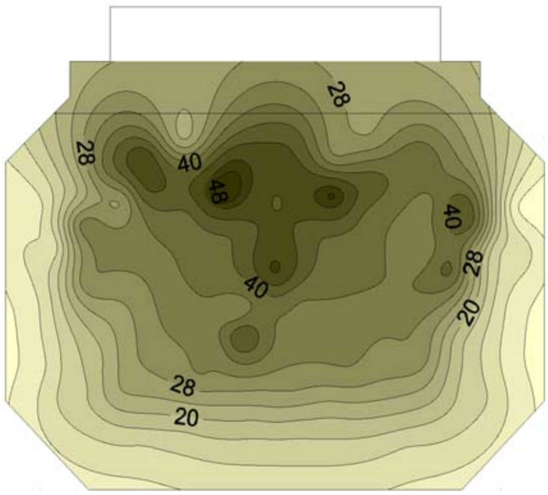

Figure 6. Distribution of ITDG – simulation.

Also in this case the simulation displays results almost identical to the measurements.
The reasons of the very high values in the centre of the stalls are the same for the high values of C80 and D50: essentially the absence of reflecting surfaces near the receivers.

ANALYSIS AND PROPOSALS

It is clear that the theatre is not suitable for music representations, but it presents some problems also for drama. These problems are particularly relevant in two zones placed in the centre of the stalls: here the intelligibility of the sound is not optimal (C80 less than 4 dB) and the sensation of a hypothetical member of the audience is like being far away from the actors or the speaker on the stage. The reason for both problems is the excessive width of the hall: the 30 m distance between the side walls makes important reflections to come with a large delay after the direct sound.
As it is impossible to reduce the width of the hall we propose the introduction of a special panel hanging from the ceiling and other two panels placed on the sides of the boccascena:

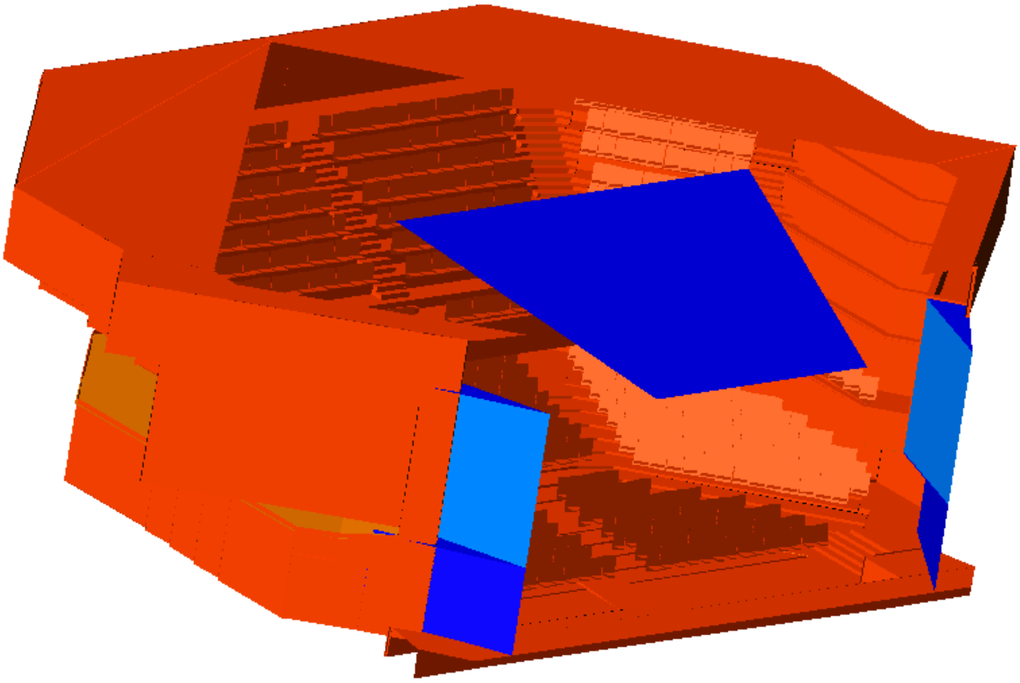

Figure 7. The proposed panels.

After the introduction of the first panel, the ceiling behaves as a "secondary acoustic source". The shape of the panel was optimized for capturing a large quantity of sound rays coming from the source on the stage and redirecting them only to a limited zone, corresponding to the center of the stalls.
The two panels on the sides of the stage, because of the far position with respect to the centre of the hall do not contribute to increase the Clarity and Definition parameter of the whole stalls.
The simulation with the panels gives the following results:

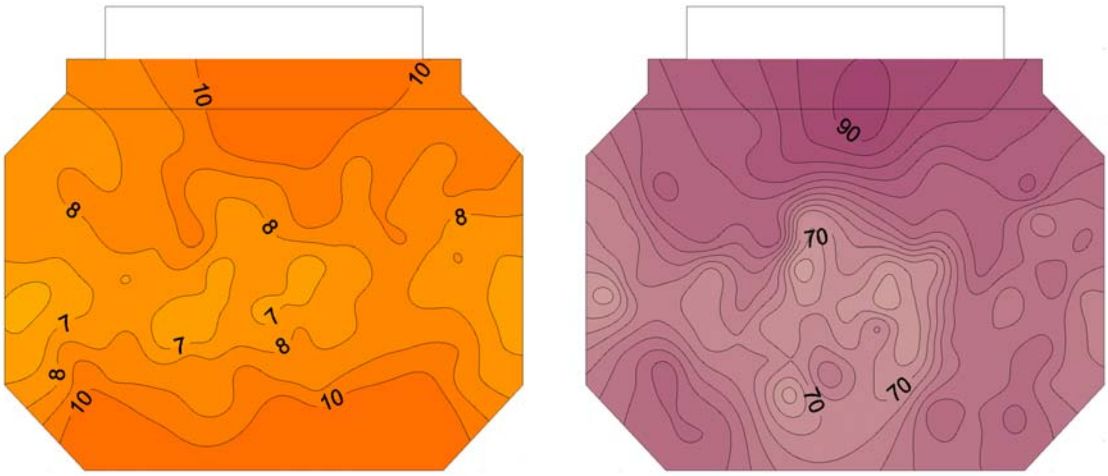

Figure 8. Simulation of the distribution of C80 and D50 after the introduction of the panels.

As we can see from the above maps after the introduction of the panels the dip with low values of the clarity index in the stalls is almost vanished and all the stalls display values of 8 dB. (except for the first rows near the stage).
The introduction of the panel hanging from the ceiling implies also a noticeable decrease (15-20 ms) of ITDG values in the stalls giving to the listener the sensation to be near the stage. It is of fundamental importance that the influence of the panel is limited only to the center of the stalls otherwise the increase of the C80 and D50 would affect all the stalls keeping a great difference among different positions.

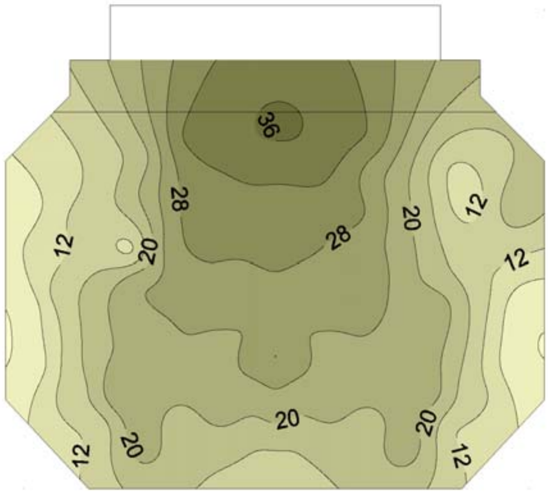

Figure 9. Simulation of the distribution of ITDG after the introduction of the panels.

Another important consequence following the introduction of the panels is the increase of the reverberation time. This aspect is significant considering that the management is thinking about the use of the theatre for musical representations.

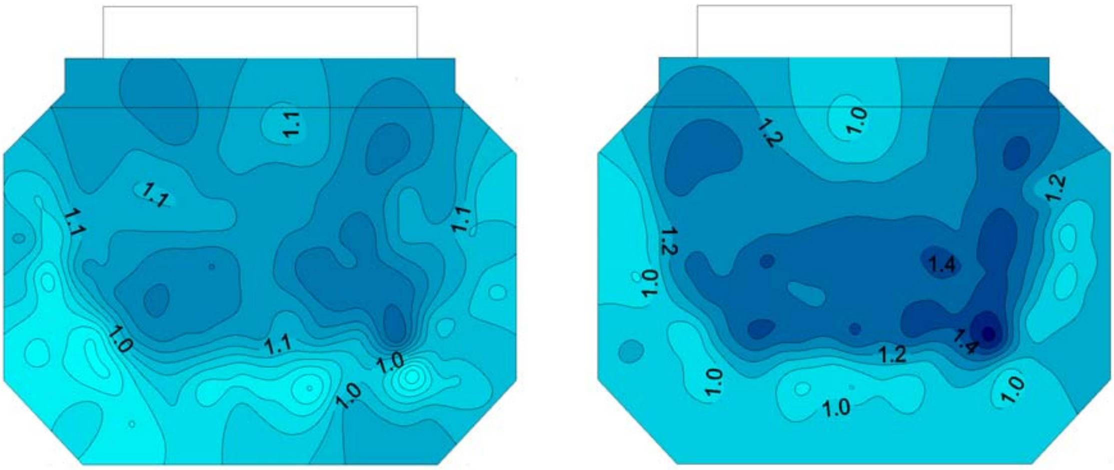

Figure 10. Simulation distribution of the RT30 before and after the introduction of the panels.