ICSV13 - Vienna
The Thirteenth International Congress on Sound and Vibration
Vienna, Austria, July 2-6, 2006

THE "MARIA REGINA DELLA PACE" CHURCH IN PERUGIA: ACOUSTIC MEASUREMENTS AND CORRECTION DESIGN

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Abstract

The acoustic performances of a modern church were investigated. The church is located in Perugia (Umbria, Italy), it was built in 1993 and it has a volume of 9.000 m^3. A measurement campaign was carried out, in order to evaluate the main acoustic parameters in the current situation and to propose a corrective solution. The acoustic correction was evaluated using *RAMSETE*, a simulation and forecast acoustic software.

INTRODUCTION

Indoor acoustic comfort is very important because it allows to have a good intelligibility of the acoustic message, intended as talking language and as music. In the present paper a case study of a church is investigated; the "Maria Regina della Pace" church, situated in Perugia (Umbria, Italy), even if it was built in 1993, presents acoustic problems. Therefore a measurement campaign was carried out and in particular reverberation time τ_{60}, RASTI, STI, clarity C_{80} and definition D were measured in many different points of the church. Results showed that the church has no good behaviour, especially due to the high reverberation time values. The calculation programme "Ramsete" was used to propose a corrective solution; different simulations, corresponding to various solutions of acoustic correction, were carried out: as final configuration the one allowing to reach the acoustic required performances was chosen. The experimental results and the design of the final acoustic correction solution are presented in the paper.

CHURCH DESCRIPTION

The “Maria Regina della Pace” church is located in Perugia, Umbria, Italy. The church building, started in 1991, was finished in 1993, so it is a modern church. The building architecture has many symbolic meaning: the church plan has a fish form, to remember the S. Pietro’s miraculous fishing; indoor structure is shaped upon this form, in compliance with the liturgical requirements.
Figure 1 shows the plan and the front view of the church.

a)

b)

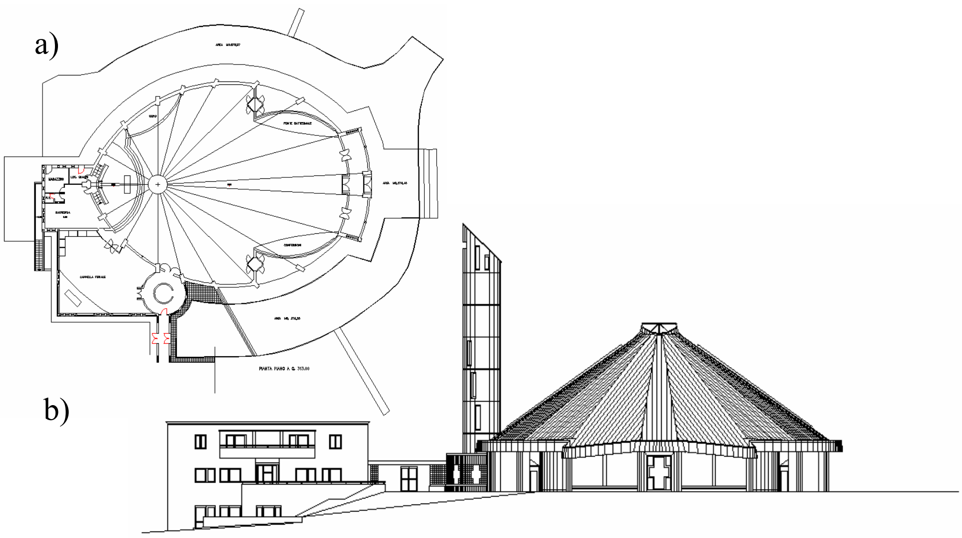

Fig. 1 – Plan (a) and front view (b) of the church

The presbytery corresponds to the fish head, the reunion hall to the body, the Spiritual Birth Chapel within the font is the right fin and the Rebirth Chapel is the left one; finally the solemn entrance is the tail. The church, viewed from the presbytery, has a curtain form; the big beams of the structure, viewed from the altar, enclose the reunion.

Many architectural elements (floor, altar, ambo and font) are made of marble. The windows are made of blowed glass, the pews of oak wood; the inner covering, which gave many problems in the modeling due to the ovoid form of the plan, is made of lamellar wood, while the external covering is made of copper.

MEASUREMENT METHODOLOGY AND RESULTS

The acoustic measurements reverberation time τ_{60}, clarity index C_{80}, definition index D, RASTI and STI were carried out through the Symphonie system by 01 dB – Stell, in compliance with ISO/FDIS 3382 [1]. Figure 2 shows a scheme of the experimental apparatus.

The MLS signal generated by Symphonie was amplified, emitted by a dodecahedral source and then it was take back by a microphone situated at 1,20 m from the floor.

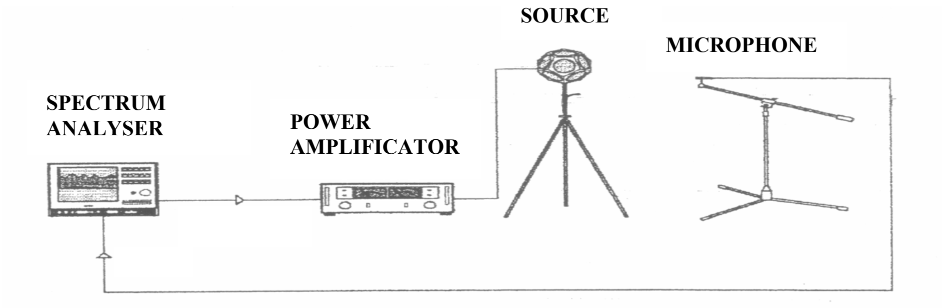

Fig. 2 – Scheme of the experimental apparatus

Measurements were carried out with 4 source positions and for each of them in 22 microphone positions, as showed in figure 3.

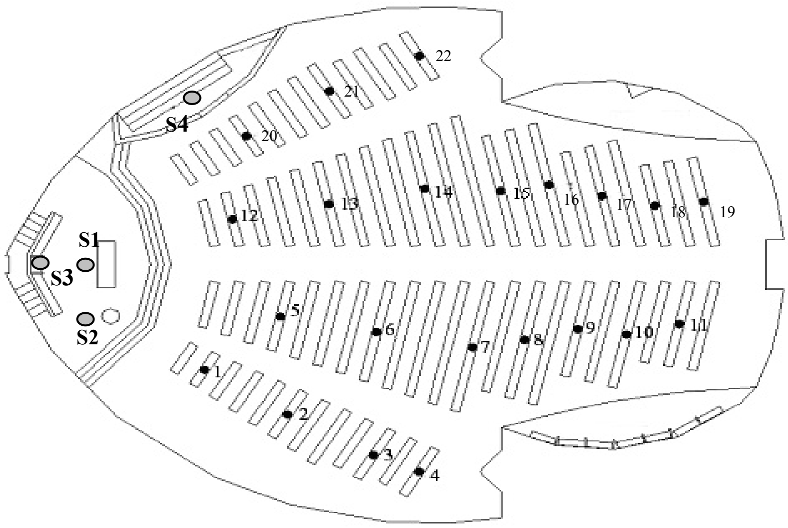

Fig. 3 – Measurement and source positions

The optimal acoustic parameters for the church activities could be deduced from Literature [2], knowing the room volume (9.000 m^3); they are then compared to the measured data, in order to evaluate the acoustic quality of the church. Figure 4 shows the mean values of the measured parameters related to the source position n. 1 (behind the altar) and the comparison with the optimal ones when the church is used for speech listening. Figure 5 shows the mean values of the measured parameters related to the source position n. 4 (chorus) and the comparison with the optimal ones when the church is used is for music listenig. Table 2 shows a sinthesys of the measurements results.

An important acoustic parameter, when the church is used for speech listening, is the RASTI index; the RASTI main value related to the source position n. 1 is 0,35, the corresponding RASTI acoustic quality class is “Low”.

Finally results show that it is necessary an acoustic correction to improve both the speech and the music listenig quality.

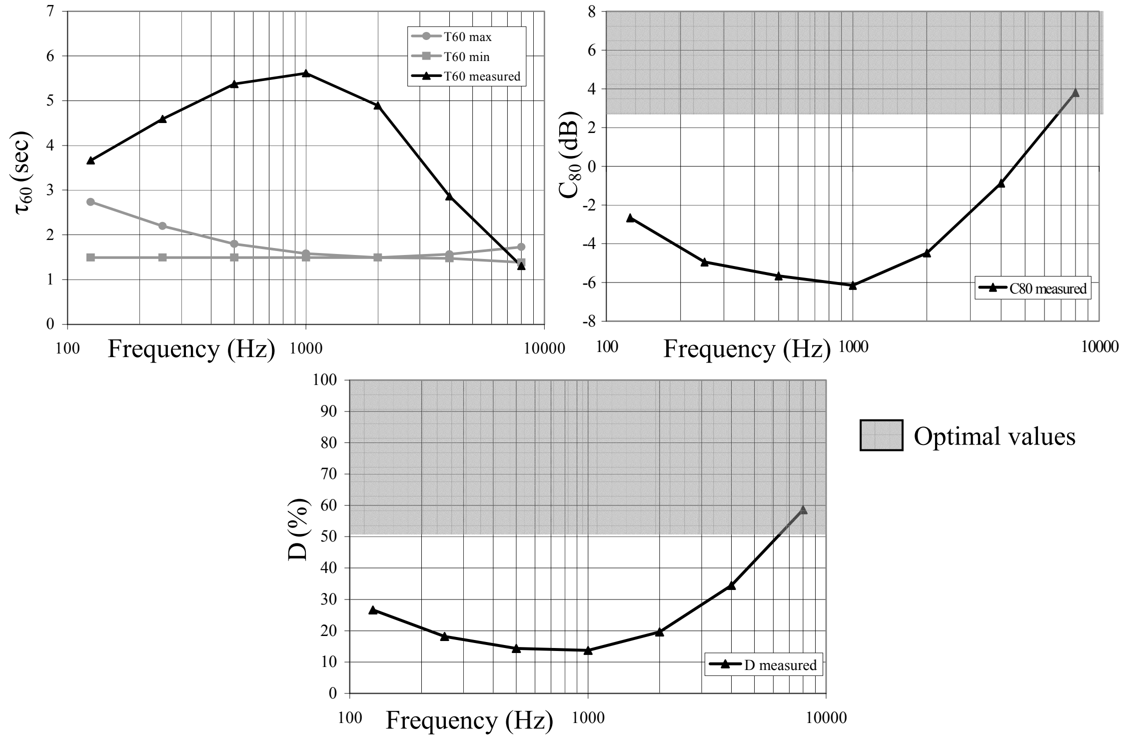

Fig. 4 – Source position n. 1: optimal values for speech listenig and mean measured ones

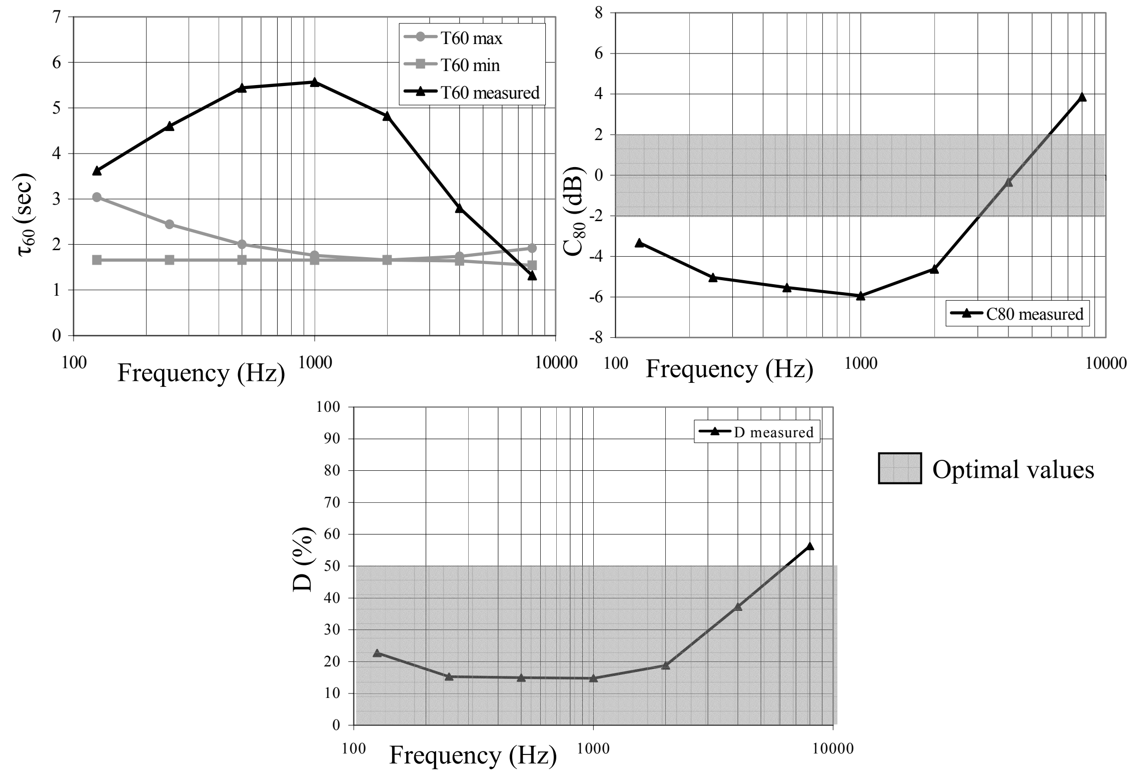

Fig. 5 – Source position n. 4: optimal values for music listening and mean measured ones

	ACOUSTIC PARAMETER	COMPARISON WITH THE OPTIMAL RANGE
SPEECH (S1)	τ_{60}	TOO HIGH
	C_{80}	TOO LOW
	D	TOO LOW
	RASTI	TOO LOW
MUSIC (S4)	τ_{60}	TOO HIGH
	C_{80}	TOO LOW
	D	GOOD

Tab. 2 – Sinthesys of the measurements results

THE SIMULATION PROGRAMME

Ramsete software [3, 4] is an acoustic simulation and forecast model based on geometrical acoustics and on an algorithm tracing separate pyramidal rays, called *Pyramid tracing*. It has a functional structure divided in several blocks: *Ramsete CAD*, *Ramsete TRACER* and *Ramsete View*.

Through *Ramsete CAD* block it is possible to model the room, to assign the acoustic material properties and to locate the source and the listening sounders. After the model definition, the software, through *Ramsete TRACER* block, starts to trace divergent pyramidal rays, providing different acoustic indicator values, such as:

- **level**: it is related to the pyramidal rays traced by the source; the number of pyramids is 8x2^L, where L is the level value. In our project N = 8 (2048 pyramids);
- **time**: it is the time of each ray way. Its value must be approximately as the reverberation time; in our project it is 10,2 seconds;
- **time resolution**: it is the time range of the response taken on listening positions; in our case, time resolution is 0,001 seconds (maximum resolution);
- **history**: it is the number of reflections of each ray before stopping. It was set the value 100;
- **humidity**: relative humidity; it was set the value 50%;
- **temperature**: temperature air; in our project it is 8°C.

After the parameters setting, the simulation starts and at the end the different acoustic indicator values are read through *Ramsete view* block.

THE CALIBRATION MODEL

Table 3 shows the acoustic material properties inserted in the model and Figure 6 the 3D church model.

Frequency (Hz)	125	250	500	1000	2000	4000	8000
pews	0,14	0,1	0,08	0,07	0,09	0,18	0,3
roof	0,15	0,1	0,08	0,06	0,09	0,18	0,3
blown glass	0,35	0,18	0,095	0,08	0,07	0,1	0,2
plaster	0,06	0,04	0,03	0,04	0,045	0,09	0,15
marble floor	0,035	0,015	0,02	0,03	0,035	0,07	0,15
windows glass	0,05	0,03	0,02	0,02	0,03	0,02	0,01

Tab. 3 – Acoustic material properties used in the calibration

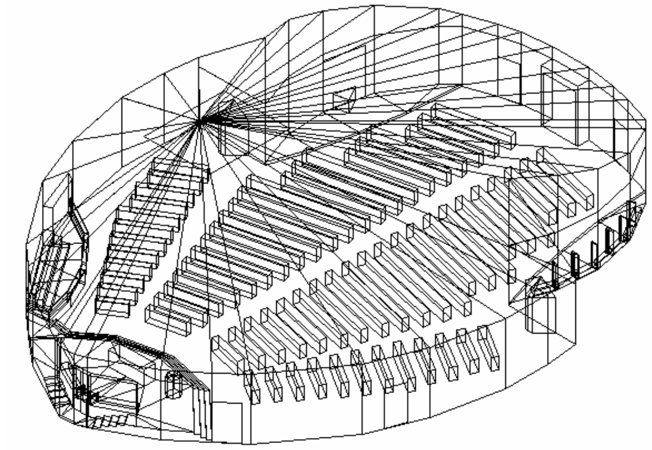

Fig. 6 – 3D church model

The acoustic simulation was carried out in the S1 and S4 source positions. To calibrate the model, the simulation results were compared to the measured values. As an example, Table 4 shows the calibration results in S1.

	ACOUSTIC PARAMETER	DIFFERENCE BETWEEN THE SIMULATION AND THE MEASUREMENT VALUES
SPEECH (S1)	τ_{60}	0,43 s
	C_{80}	0,69 dB
	D	8,9 %
	RASTI	9%

Tab. 4 – Mean calibration results with source in S1

PROPOSED SOLUTIONS

In order to improve the acoustic quality, the simulation was carried out with the virtual model developed by Ramsete software, considering the introduction of:

- a special acoustic plaster, based on vermiculite and resine and with a specific density of 300 kg/m^3, applied on the walls, for a total surface of 200 m^2.
- resonant panels over the roof;
- presence of people, giving to pews the right acoustic absorption coefficients.

Table 5 shows the acoustic absorption coefficients vs. the frequency inserted for the acoustic correction.

Frequency (Hz)	125	250	500	1000	2000	4000	8000
people	0,5	0,66	0,8	0,85	0,9	0,58	0,5
acoustic plaster	0,048	0,182	0,402	0,52	0,48	0,27	0,2
resonant panels	0,2	0,56	0,26	0,1	0,026	0,013	0,013

Tab. 5 – Acoustic absorption coefficients

After the simulation, the acoustic parameters obtained in S1 and S4 source positions were analysed. Figure 7 and 8 show the related mean acoustic parameters and the comparison with the optimal range.

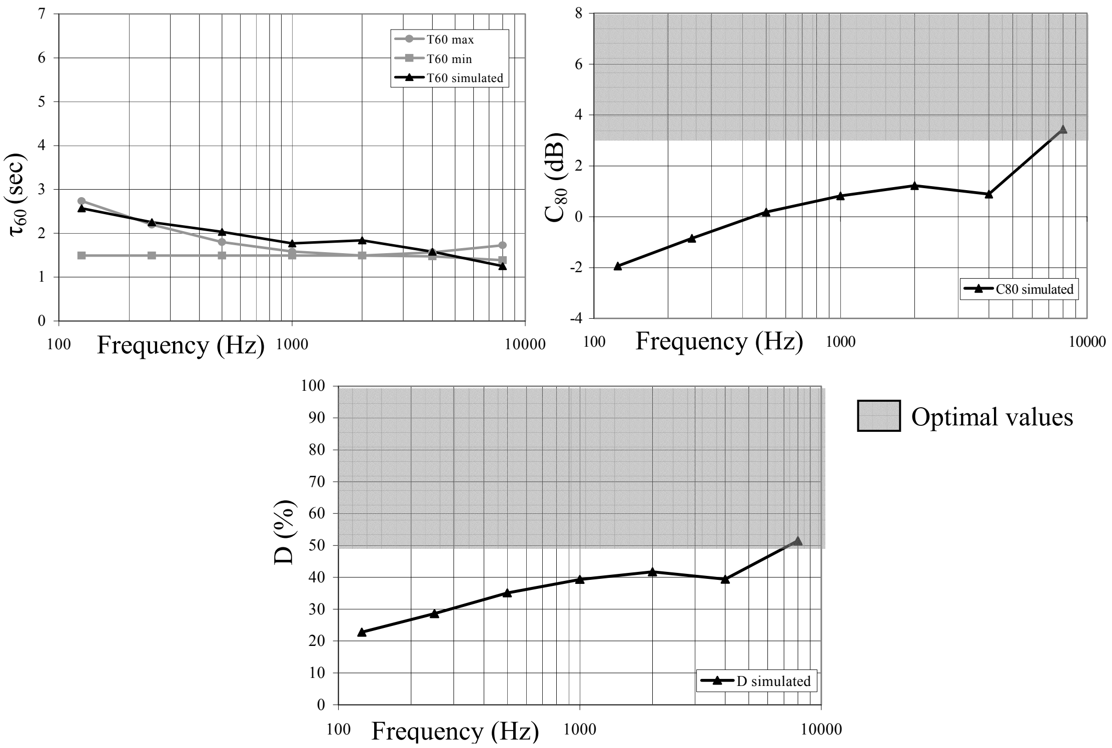

Fig. 7 – Source position n. 1: optimal values for speech listening and simulated parameters

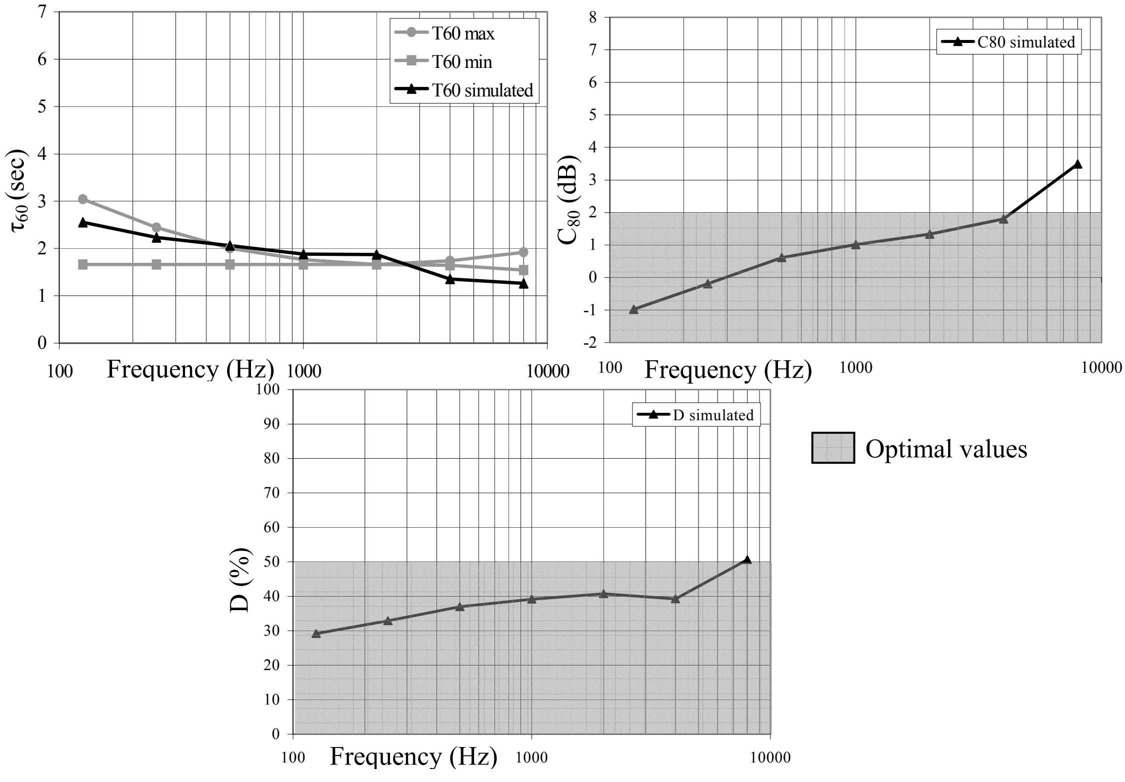

Fig. 8 – Source position n. 4: optimal values for music listening and simulated parameters

In S1:
- τ_{60} is quite good in the considered frequency range;
- C_{80} and D are still low, but there is an improvement of 55% and 65% respectively with respect to the measured values;
- the RASTI mean value is 0.35, so there is not any improvement.

In S4:
- τ_{60} is quite good in the considered frequency range;
- C_{80} and D are acceptable in all frequencies range, except at 8000 Hz.

CONCLUSIONS

The acoustic quality of Maria Regina della Pace church in Perugia was defined by a measurement campaign. An omni-directional source in 4 positions and 22 receiver points were located in the church, in order to measure the reverberation time, clarity, definition and RASTI indexes. Results showed that it was necessary an acoustic correction to improve the speech and the music listening quality. Therefore the room acoustic quality was verified using RAMSETE, a simulation and forecast acoustic software, which allows the room modelling through plane surfaces with their acoustic absorption coefficients.

The acoustic simulation was carried out with a virtual model developed by Ramsete, considering the introduction of a special acoustic plaster, resonant panels over the roof and presence of people. The following parameters in the S1 and S4 position were calculated: reverberation time τ_{60}, clarity index C_{80}, definition index D, RASTI index and then they were compared to the optimal values.

In the both position S1 and S4 the τ_{60} values, related to the initial configuration, were quite good. C_{80} and D values in S1 were still low, but in S4 were acceptable; the RASTI values are nearly the same as before correction.

Finally, in order to obtain a good acoustic quality it is necessary the installation of an electroacoustic sound system.

REFERENCES

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