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The acoustic performances of Cucinelli's theatre: from the design to the test measurement session

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ABSTRACT

The aim of the work is to show a full design development to optimize the acoustic performances of the new Cucinelli's Theatre, by using simulation softwares and instrumental measurement sessions. Solomeo is a small medieval village near Perugia, where Mr. Brunello Cucinelli decided to build a new classic theatre: the architectural design is inspired by the Italian Renaissance theatre of Vincenzo Scamozzi in Sabbioneta. Building works started in 2007 and the acoustic study began during 2008, with a preliminary measurement session of the main room acoustic indexes such as Reverberation Time, Clarity and Definition Indexes, Speech Transmission Index in 57 positions. Different measurement sessions were carried out during the theatre's realization, accompanied by simulation sessions which allowed to choose right materials and furniture, in order to obtain a very good acoustic quality. A final measurement session was carried out before the opening ceremony, in order to control the acoustical parameters and to check the shifting between output simulation data and instrumental data. Software output gave a little over-evaluation of some indexes if compared to the real ones, nevertheless the theatre's acoustic performances are very good.

1. INTRODUCTION

The Latin classic theatre and the works of Vincenzo Scamozzi during the Renaissance in Parma and Sabbioneta inspired Mr. Brunello Cucinelli that decided to build in the hamlet of Solomeo a theatre perfectly integrated in the urban texture of the small village, matching with the Umbria hill's landscape. Starting from the original design, the acoustic performances of the theatre were gradually becoming one of the most important goal. The idea was to obtain a good acoustic behaviour without radically change the structural and architectural planning, but just using furnishings and materials that can optimize the listening conditions.

The measurement session was divided mainly into two phases: the first one was carried on while the building was in a raw condition, during the month of November and December 2007; the second phase was developed some weeks before the opening ceremony during the summer of 2008.

2. THEATRE'S FEATURES

The theatre measures 38 by 13 meters and is a 10 meters tall to the caves. The main entrance insist on the foyer and then, after a short passage beneath the circle, leads to the auditorium. The theatre has 230 seats, including those on tiers of the cavea below the circle. The stage, 12 meters wide and 8 meters deep, has a 7 meters proscenium. The theatre façade is covered with panels hewn from local stone and a long window panel provides lighting to the main hall (Figure 1); this panel can be

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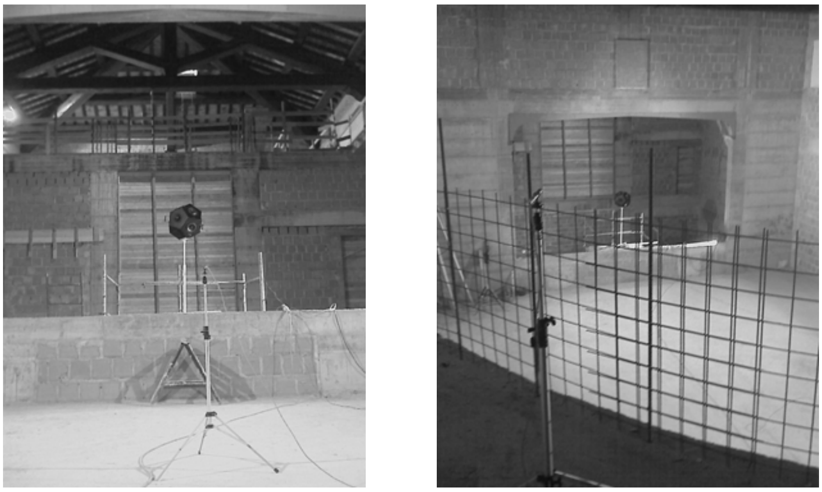
darkened using an automatic system of blinds. The hipped roof is covered with tiles and pan-tiles, Inside the building is the stage, auditorium and circle, which terminates in a wide exedra decorated with an order of Ionic pilasters. The wall of stage is almost completely bared, except for two Corinthian pilasters that border the proscenium. The roof trusses represent also a decorative element.

Figure 1: Cucinelli's theatre, the main entrance.

3. MEASUREMENTS RESULTS (PHASE 1)

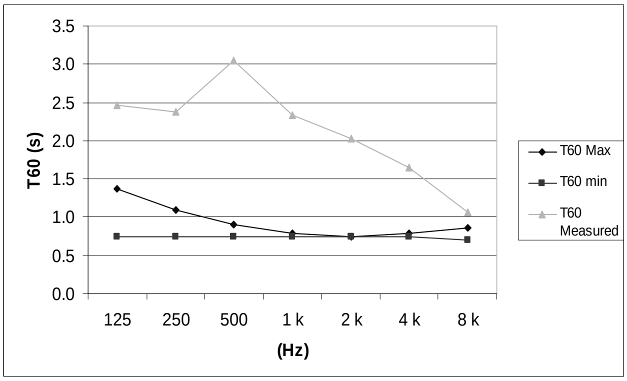
The measurement session in the phase 1 was necessary to understand the acoustic situation given just by the architectural choices and the disposal of volumes inside the room. The source was positioned at the centre of the stage, 1.6 m high; the microphones positions are 57, covering all the spaces doomed to the public, the height of microphone changes from position to position in order to reproduce the real listening conditions in the auditorium, but also in the cavea and in the circle (Figure 2a and 2b) . The signal used in both the two phases was MLS.



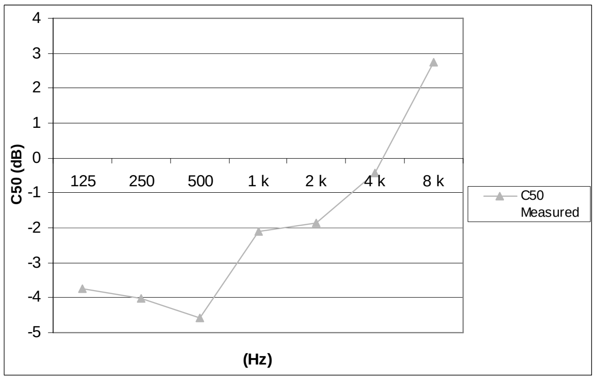
a) b)

Figure 2: The source and the microphone during a measurement session in the auditorium a), in the circle b).

Results show a situation that obviously don't fit well with the optimal range, but the shape of the room lead to acoustic parameters values that are not strongly awful. Particularly, Figure 3a put in evidence how the T_{60} had difference kept down between 0.20 s at 8 kHz and 2.15 s at 500 Hz if compared to the maximum optimal values. The same results are obtained for Clarity and Definition Indexes (Figure 3b and 3c); STI and RaSTI reach both the fairly good class.



a)



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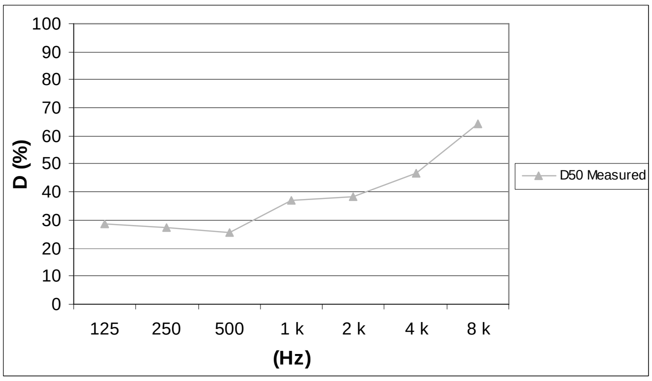

c)

Figure 3: Results of Phase 1: a) T_{60}, b) Clarity Index and c) Definition Index.

As can be see in Figure 4, the Sound Pressure Level is quite uniform all over the theatre although furnishings were not completed.

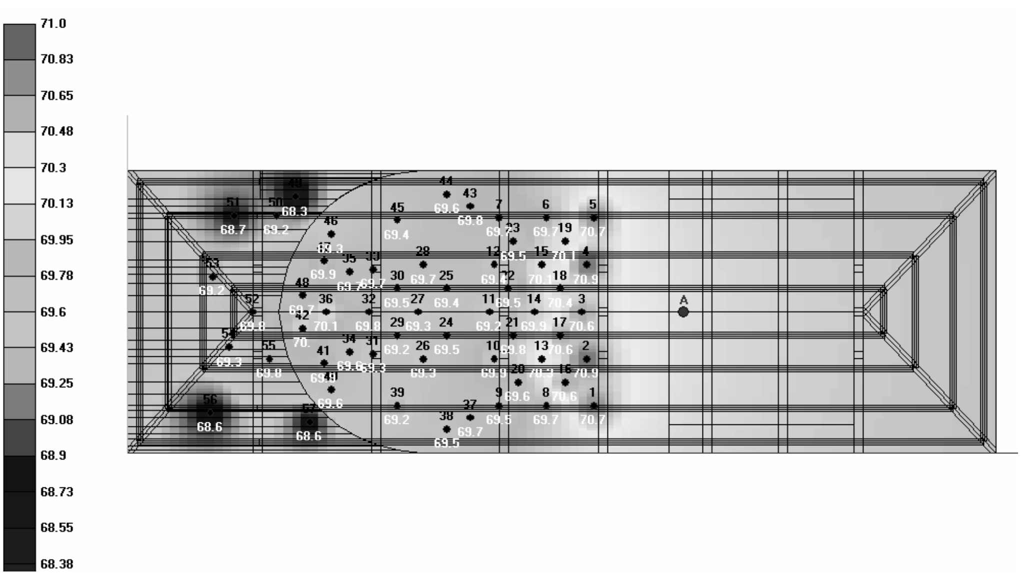

Figure 4: Results of L_{eq} in the phase 1.

4. SIMULATION AND ACOUSTIC DESIGN

The software used to develop the acoustical design of the theatre is RAMSETE, that provides to simulate the sound field based on geometrical acoustics and employs a pyramidal divergent ray tracing algorithm. The internal surfaces are realized employing the CAD tools of the software. Then each material is characterized by an absorption coefficient, taken from RAMSETE library. The model of the internal surfaces, the microphones and the source are represented in Figure 5.

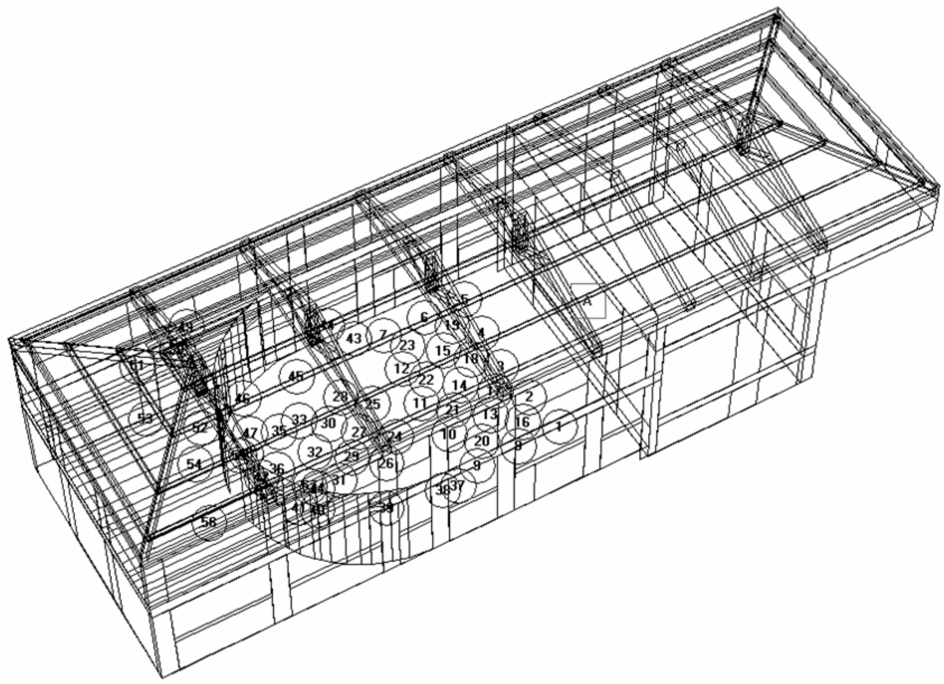

Figure 5: Cucinelli's theatre model with the 57 microphones and source positions.

The aim of the model calibration is to obtain the overlap of the acoustics parameters evaluated by RAMSETE to the measured values; when it happens the model represents the real acoustic behaviour of the room and it is possible to employ it for simulating the different design conditions. The model calibration consists in an iterative process in the calculation of acoustic power level, absorption coefficients of the materials and of two parameters α and β which characterize the acoustic decay.
Result about T_{60} are shown in Figure 6: it's possible to underline the perfect fit between the two curves. The gap between the measured data and the calculated ones is negligible also for all the other considered parameters.

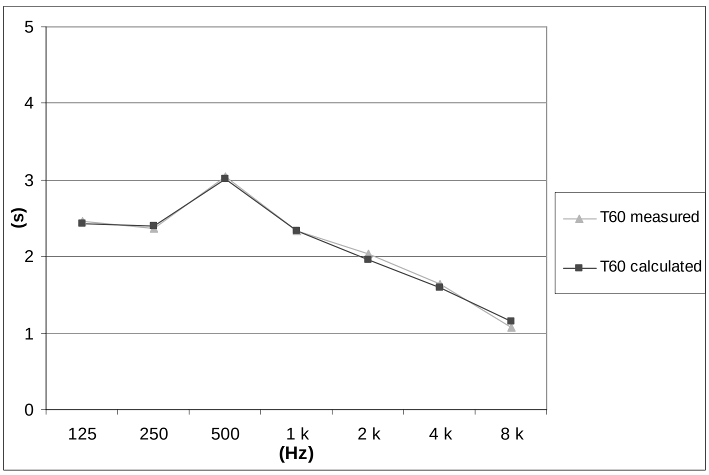

Figure 6: T_{60} model calibration of the Cucinelli's theatre.

The development of the acoustic design took place trying to respect the original idea. Many simulations were carried out to extrapolate the best one. First of all, it was decided to operate in the

largest surface of the room: the internal walls. The model was defined introducing both a normal and an acoustic plaster. In order to optimize the performances and thus reducing installation costs, the simulations were conducted increasing gradually the acoustic plaster surface. After a wide market research, it was found a product that was extremely bio-compatible: in fact the plaster texture components are cork, clay and diatomite dust, which mixed together create alveolus and cavity with high absorption coefficient (0.60 > α > 0.80 between 600 Hz and 5 kHz). Moreover, another design choice provides to finish off the stage walls with common smooth plaster, avoiding an undesirable sound absorption or better still to support sound waves diffusion.
The total surface is about 800 m^2 and in the different solutions the acoustic plaster surface raise from 146 m^2 up to 435 m^2.
A second important step design was the definition of the furnishings like chairs, cavea's pillows and curtains. The selection falls into materials tested in compliance with ISO 354 that ensure good acoustic absorption (α > 0.70).
For the sake of brevity, in Figure 7 are shown only the last three solutions developed with the software. In particular, from the first solution to the last one the acoustic plaster surface is changed together with the quality of chairs. The benefits are clearly visible with a down translation of the curve to the optimal range. The same responses were obtained for the other acoustic parameters.

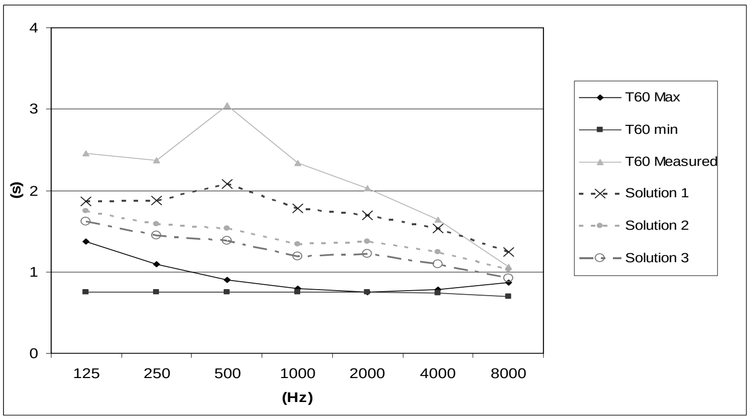

Figure 7: T_{60} measured values, design simulation results and optimal range.

5. TEST MEASUREMENT SESSION (PHASE 2)

Finally, a last measurement session was carried on before the opening ceremony: it was useful and interesting to have a comparison between the design values and the real Cucinelli's Theatre acoustic performances (Fig. 8).

a) b) c)

Figure 8: Test measurement session: a) in the auditorium, b) in the cavea and c) in the circle.

T_{60} values measured in phase 1 and phase 2 and compared to the optimal range and to the design solution are shown in Figure 9. It's interesting to observe how the Test-curve and the Solution 3-curve follow the same trend. The differences between the test values and the maximum range values are included between 0.14 s and 0.73 s.

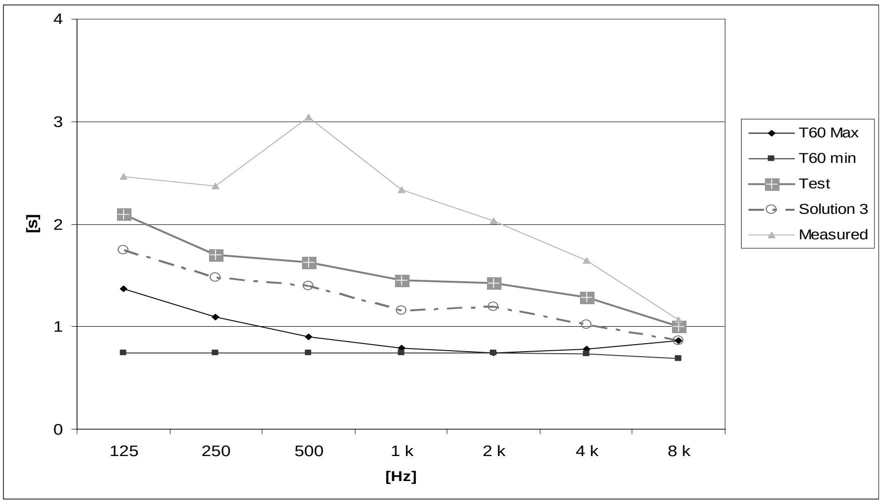

Figure 9: T_{60} test measurement session results vs. T_{60} values on measured session and T_{60} optimal values.

As for the reverberation time, also for Clarity and Definition indexes the solutions studied in the design session lead the acoustic quality of Cucinelli's Theatre to a good level. Particularly, in Table 1 are reported the values of Clarity that fall quite in total in the optimal range (-2 dB > C > + 2 dB).

Table 1: Clarity test measurement session results.

Frequency (Hz)	125	250	500	1 k	2 k	4 k	8 k
C Test results (dB)	-2,96	-2,23	-2,15	-0,69	-1,16	-0,65	1,86

Finally in Figure 10 is shown the spatial distribution of STI in the Test condition: it's possible to mark a good spatial distribution in all the three zones of the Theatre, auditorium, cavea and circle. The STI remain in the fairly good class but getting closer to the upper one.

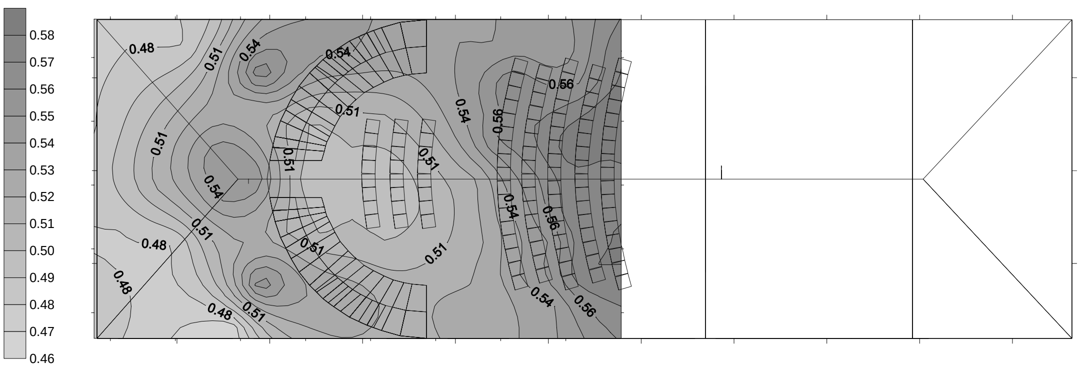

Figure 10: Spatial distribution of STI in the Test measurement session.

6. CONCLUSIONS

The aim of this work was to show a complete acoustic design development for the Cucinelli's Theatre in Solomeo. The original idea of the theatre trace the Italian Renaissance theatre of Vincenzo Scamozzi in Sabbioneta and in Parma. These are optimal examples of theatres, therefore

the design idea wanted to respect the main features of them: moreover, the operative step start when the great part of the structure was built. By means of a measurement session, it was possibile to define the acoustic parameters values such as Reverberation Time, Clarity, Definition, STI and RaSTI. These first results were later used to develop a model in a software and using the simulation output to study the real behaviour of the room by choosing various acoustic materials and furnishings. The first step was the calibration of the model: by using the library of the software, it was possible to have a perfect fit between the values obtained in the first measurement session and the software output. The data output curve follow qualitatively and numerically at each frequency the values obtained during the surveys: for instance the difference for T_{60} fluctuate between 0.01 s and 0.08 s. After that the behaviour of the model could be regarded as the real one and the study of different solutions could start to optimize the acoustic performances of the room.
Before the opening ceremony it was carried out a new measurement session, to verify the choices made in the design development. The experimental results show how the improvement of the acoustic parameters was very strong as regards the phase 1 measurement, when the Theatre was still undefined. The most important result of this study is that measurement session curve and output simulation curve had the same trend. The software gives light overestimated results, but finally the Cucinelli's Theatre acoustic could be judged very good if compared to the standard optimal range in the Literature.
Moreover, the feedback given by the audience and by the actors during this first season were very good; therefore, thanks also to these subjective impressions, the goal to optimize the acoustic properties of the Theatre was achieved.

ACKNOWLEDGMENTS

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