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The Royal Church of San Lorenzo in Turin: Guarino Guarini and the Baroque architectural acoustics

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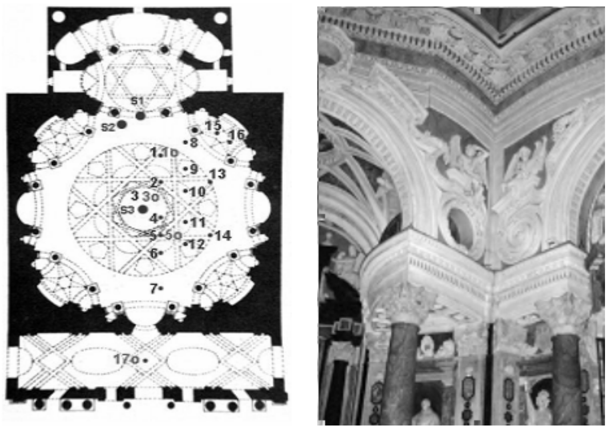
In 1666 the architect Guarino Guarini received from Carlo Emanuele II, Duke of Savoy, the appointment to build in Turin a new church dedicated to S. Lorenzo. The architect conceived a design in Baroque style with a very particular ribbed dome and this peculiarity is a very hard to find feature throughout Europe. Acoustics measurements were performed in S. Lorenzo in order to investigate how this unique architecture affects the response parameters used in architectural acoustics. Results are discussed in this paper, comparing to the methodology suggested by Cirillo and Martellotta in order to characterize the acoustics of churches.

1 Introduction

In 1666, Duke Emmanuel Philibert II of Savoy appointed to Guarino Guarini the design of San Lorenzo church in Turin. Mathematician, theologian and, above all, architect, he conceived an octagonal central plan church. The building has a very peculiar inner composition: neither straight lines, nor regular volumes or parallel walls are present (Fig. 1a). It is composed by two coupled volume (main room and Crucifix Chapel that consists of a roughly rectangular shape). The main room is divided in two volumes: the bigger consist of a central plan room and the second one consist of en ellipsoid plan room. All the lateral chapels, the dripstones (Fig. 1b), and whatever may be found inside the church, show a curved profile.



a) b)

Fig. 1 a) Plan of the San Lorenzo church with measurement positions; b) particular of the dripstones curved profile

Acoustic measurements were carried out in the positions shown in Fig. 1a. The source was located in three different positions: behind the altar, behind the lectern position and in the middle of the central plane. We choose 17 receiver positions located only in a half of the central plan. The points displayed with an "°" stand for measurements performed with the heavy dividing door open between the two coupled volume.

2 Measurements and results

Impulse response measurements were carried out using the sine sweep technique, generating two sine sweeps for each of the three positions of the sound source (s1, s2, s3); taking advantage to its symmetry, the source was placed in the left part of the building only. Several measurements were performed for source in the first position (s1) and for the second position (s2) in order to investigate how the sound field may change due to this particular architecture.

The measurements were then analyzed with Adobe Audition® and Dirac® software, in order to determine the acoustical descriptors according to ISO-3382 and IEC-60268-16 [1].

The average reverberation time measured in the church main volume is shown in figure 2. The average value of T_{30} falls in the 2-4 seconds range. This range is indicated in the literature as good for churches [2]. We can therefore conclude that the reverberation time of this church, in spite of its large dimension, provides an acceptable acoustic quality [3].

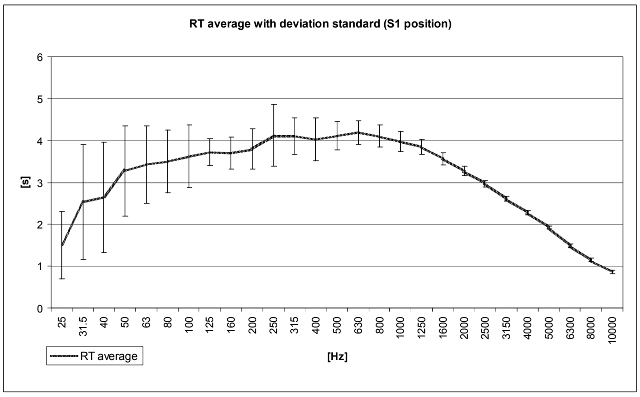


Fig. 2 Average of reverberation time for s1 source position

This particular phenomenon is probably due to the peculiar inner conformation, which determines a good sound diffusion, thus allowing a fair listening condition. Guarini did not foresee this effect: in fact he knew the scatter phenomenon but he didn't consider the sound as a frequency-dependent phenomenon [4].

So we investigated how the sound field may vary in the different positions in order to point out how the Gaurini design influences the listening.

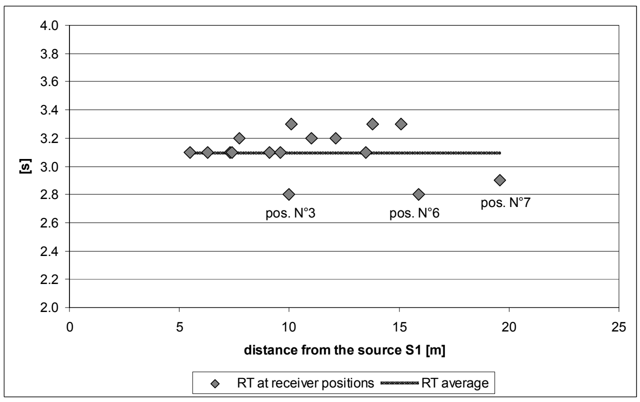


Fig. 3 comparison between average reverberation time and reverberation time in each receiver positions for s1

As shown in figure 3 the reverberation time doesn't change sensibly moving through the church. The sound field in the main room is then homogenous; the three positions that differ from the average are particular ones:

- Position 3 is under the dome and furthermore is in the center of the central plan. As explained in literature this is due to the central plan conformation of the church [5]
- Position 6 and 7 are far from the source and this cause the lowing of reverberation time.

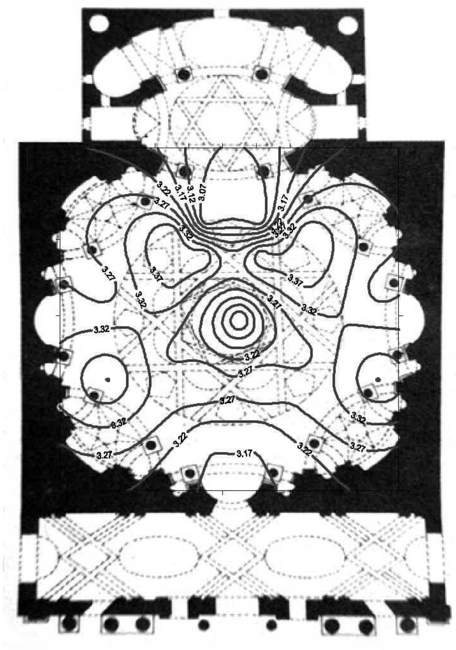


Fig. 4 average T_{30} sound field distribution

The average values and standard deviation of T_{30} at low, middle and high frequency assure us a well-blended ambient sound field (fig. 5)

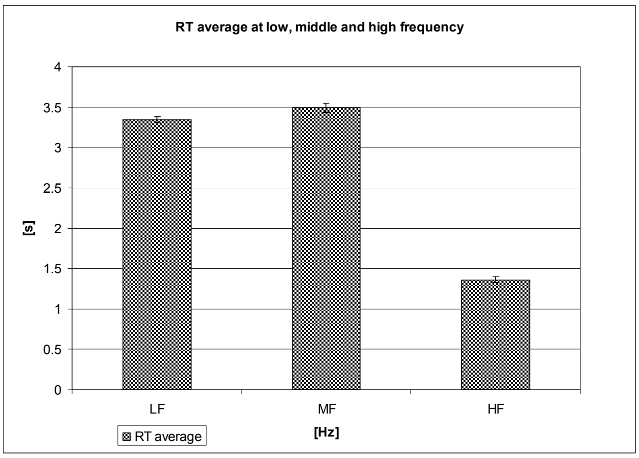
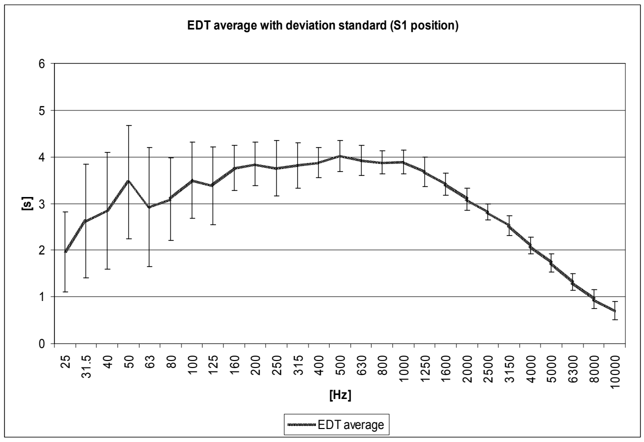


Fig. 5 Average of low, middle and high frequencies of reverberation time for s1 and their standard deviation

The comparison between T_{30} and EDT parameters (fig. 6) shows how the sound field varies among different positions. This comparison is useful to understand how the first reflections act in the receiver position.

Figure 5 shows that the reflections aren't strong enough in the receiver positions near the s1 source. This is due to strong diffusion caused by the inner architecture. From the center of the dome (about 10 meters distance from s1) the sound field becomes more homogenous reaching the aims of Guarini.



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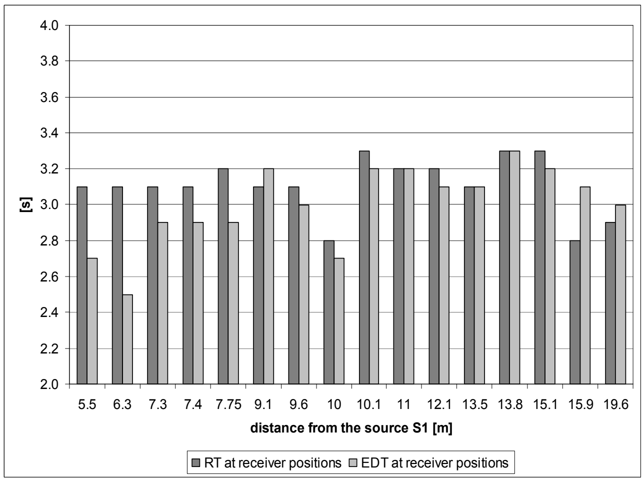


b)

Fig. 6 a) Average EDT parameter and its standard deviation b) comparison between T_{30} and EDT parameters with distance

Coupled volumes.

As one can notice in figure 1 a) the building is divided in two main volumes: the main room and the Crucifix Chapel. These volumes are divided by a heavy door which sometimes may be opened ye the priest in order to receive more people, especially in the summer.

So when the heavy door is open, the Crucifix Chapel acts as a coupled volume influencing the sound field as shown in figure 7.

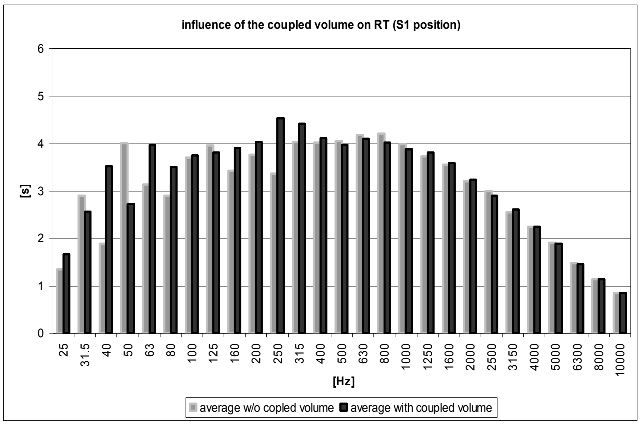


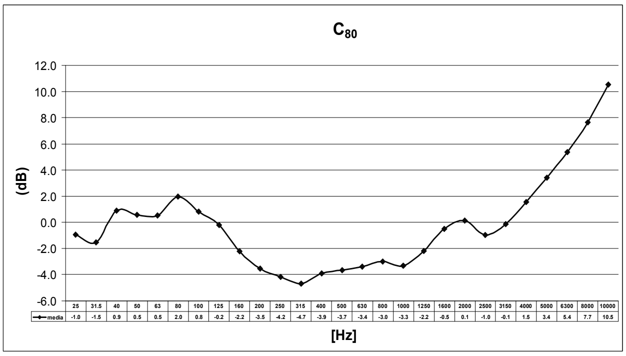
Fig. 7 Influence on the Crucifix Chapel for s1

This figure shows how the coupled volume act as an "absorber" for the low frequencies but as a slight "amplifier" for the high frequencies. However it supplies a good effort to the sound field lowing down these frequencies.

The sound field shown is the average of the three position measured with the door displayed in figure 1 a).

Other acoustical parameters.

The other acoustical parameters such as clarity (C_{80}) or definition (D_{50}) behave like the reverberation time. They show an homogenous sound field throughout the church, with typical variations of single parameter (fig. 8 a) b) c))



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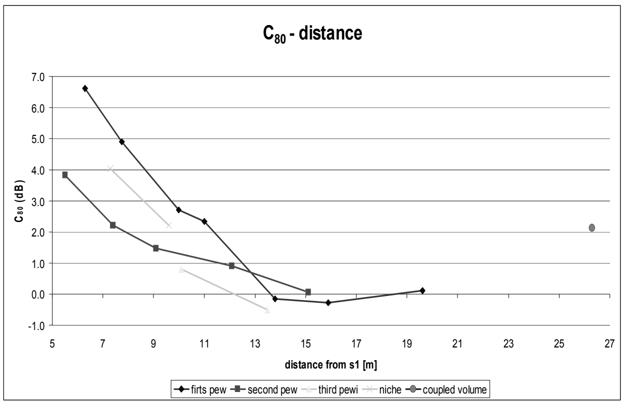

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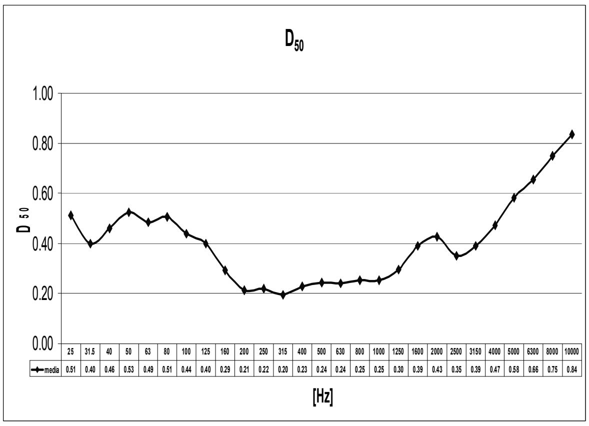

c)

Fig. 8 Other acoustical parameters for s1: a) Average of C_{80} versus frequency; b) C_{80} versus distance from s1 source; c) Average of D_{50} versus frequency

3 Comparison with other measurements methods

Many studies have been carried out on churches. In particular a new measurements standard is proposed from Cirillo and Martellotta [3]. They rightly observe that it is no more possible to use theater measurements standards in order to characterize churches. Thus, they suggest a new methods which consider fix positions of the source and a fix number of receivers. Using this standard a full comparison of classical churches may be successfully carried out. But in particular cases like the San Lorenzo church in Turin, this method couldn't be applied, as it doesn't takes into account the small dimension of this building.

4 Conclusions

In this paper the acoustical parameters of the Royal Church of San Lorenzo in Turin was investigated. The inner architecture was used to explain how this particular building has such a peculiar acoustics. The standard architectural acoustics parameters were measured in order to understand how the sound field varies in several positions. This study tested the aims of the architect, Guarino Guarini, of designing a building with fair listening and good acoustics. It shows how planning an inner architectural composition, acting as a huge diffuser, help a large room to become a good place for listening.

Acknowledgments

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