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Acoustic of worship spaces: Paper ICA2016-331

Analysis of acoustic variations due to different use configurations in the “Basilica de Santa María de Elche”, venue of the “Misteri”

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Abstract

Worship spaces are characterized by their use versatility. They are meeting places where the acoustics should be adequate for speech intelligibility but also suitable for music. Therefore, it is important to know the acoustic behavior of these spaces in both cases and the differences that occur depending on the activity being performed. In the case of the “Basilica de Santa Maria de Elche”, variations in the use of space are particularly important because in addition to worship and concerts, it is the scene where the "Misteri d'Elx" is represented. This medieval play was declared a National Monument in 1931 and included in the first Proclamation of Masterpieces of the Oral and Intangible Heritage of Humanity by UNESCO in 2001. In this paper we have carried out an acoustic simulation of the different configurations of the temple related to the activities usually developed in it in order to determine how these settings affect its acoustic behavior.

Keywords: heritage, simulation, virtual acoustics

Analysis of acoustic variations due to different use configurations in the "Basilica de Santa María de Elche", venue of the "Misteri"

1 Introduction

The Basilica of Santa Maria in Elche is known for being the scene of the representation of the "Misteri d'Elx", a theatrical representation of medieval origin declared a Masterpiece of Oral and Intangible Heritage of Humanity by UNESCO. The present church is the fourth raised in the same place and it was built between 1672 and 1784 [1] [2].

It has a Latin cross plan of a single nave covered with a barrel vault with lunettes. One each side of the nave there are four chapels between drilled buttresses which allow to walk from one chapel to another and into the transept and the ambulatory. The apse is closed by a half dome and the crossing is topped with a large dome which rests on an octagonal drum and pendentives. The perimeter promenade is repeated in the first floor. A gallery located over the chapels and the ambulatory opens to the central space throughout balconies.

As shown in Figure 1, for the "Misteri" representation, several changes take place in the interior space. The dome is covered with a painted canvas depicting the sky, furniture distribution is altered and wooden structures known as grandstands and "cadafal" are introduced. All of these create a new space in the Basilica which can modify its acoustic behaviour. Also, capacity for this use is considerably higher, occupying almost the entire lower floor and the upper balconies, which will result in a significant increase in acoustic absorption.

Figure 1: Interior space of Santa Maria prepared for worship and the "Misteri".

2 Methods

2.1 Models

As the space experiences important changes depending on its use, we built two different models from the plans of the basilica, as shown in Figure 2. We used AutoCAD, which is a more accurate software, to build a wireframe model and exported it to SketchUp to generate the polygons. SketchUp does not limit the number of sides in faces reducing the polygons needed to generate the model. Also it has a plugin that allows you to export the model to CATT-Acoustics software to perform the simulation.

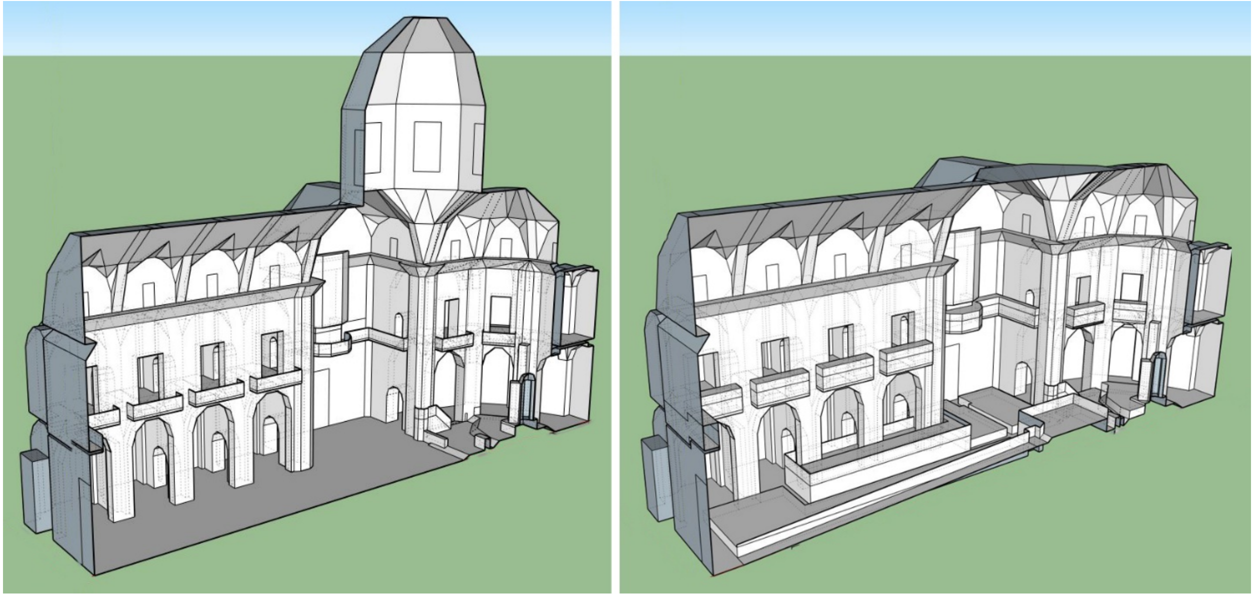


Figure 2. Geometrical 3D models created to simulate the acoustic fields of the basilica.

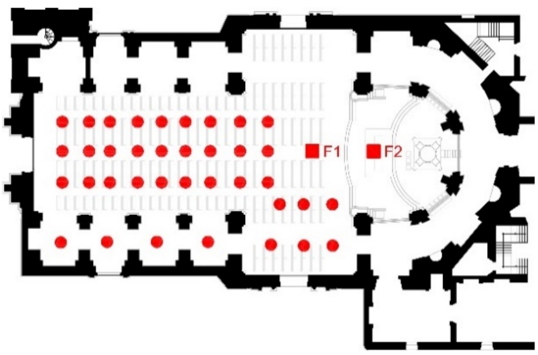
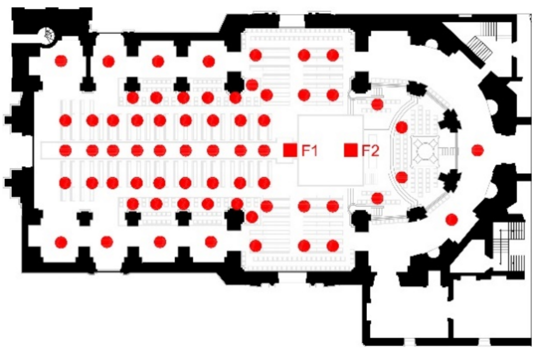
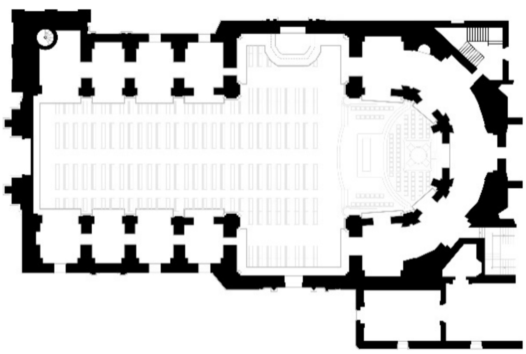
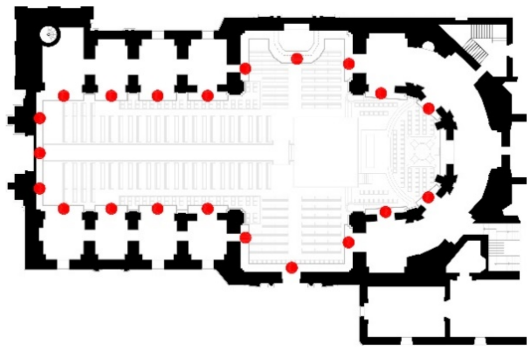
2.2 Measurement of acoustic parameters

Acoustic data has been gathered in both situations: worship and representation of the “Misteri”. It has been performed using two dodecahedral sources DO12 (Rated power 600W Sound Power> 120 dB, Frequency range: 80 Hz-6.3 kHz, directivity: almost spherical) that have been placed near the altar and in the center of the dome respectively.

We used three types of microphones. Monaural parameters have been measured with microphones G.R.A.S. Type 40 AK (Sensitivity to 250Hz 50 mV / Pa Frequency range: 3.15 Hz-20 kHz, upper limit of dynamic range (3% distortion): 164 dBre. 20µPa, lower limit of dynamic range: 14 dB, re. 20µ Pa).

For spatial parameters we used a multipattern microphone AT4050 / CM5 (frequency range: 20-20000 Hz, sensitivity: 15.8 mV, polar patterns: cardioid, omni, figure-of-eight) and its corresponding phantom power supply. Finally, the measurement of the binaural parameters was performed with a head HMS III.0 (frequency range: 3 Hz-20 kHz, -3 dB / + 0.1 dB; dynamic range: typ> 118 dB, max SPL 145 dB). The acquisition and subsequent calculation of measures has been made with the WinMLS software.

Table 1: Receivers and sources positions measured

	Worship	"Misteri"
Ground floor		
Upper floor		

For worship configuration we measured 37 receiver positions, all of them located in the ground floor as the upper floor is not used in this case. Table 1 shows how the receiver positions have been spread through the nave, the chapels of the Epistle Side and that side of the transept. It also displays that for the "Misteri" configuration the number of receiver positions registered has been increased including the wooden grandstands, the ambulatory, the apse and the balconies of the upper floor because the audience occupies these spaces during the representation. However, for the present comparison, we used only the same 37 positions measured for worship.

2.3 Simulation

We started working with the worship configuration model. It was built using Sketchup 3D modeling software and exported to CATT-Acoustics in order to perform the acoustic simulation.

After debugging the model, an absorption coefficient has been assigned to each material. We used standardized absorption values because in-situ measurements had not been processed yet. Also we intend to compare these results with simulation using absorption coefficients measured in situ [3][4].

Table 2: Materials and absorption (up) and diffusion (down) coefficients used in simulation

Material	Area %	Coefficients					
		125	250	500	1000	2000	4000
Stone masonry	67.4	0.038 0.12	0.038 0.13	0.04 0.14	0.048 0.15	0.05 0.16	0.028 0.17
Vaults	12.7	0.038 0.20	0.038 0.24	0.04 0.28	0.048 0.32	0.05 0.36	0.028 0.40
Marble floor	7.9	0.01 0.12	0.01 0.13	0.01 0.14	0.01 0.15	0.02 0.16	0.02 0.17
Dome	2.6	0.12 0.20	0.10 0.24	0.08 0.28	0.06 0.32	0.06 0.36	0.06 0.40
Wooden pews	5.1	0.09 0.30	0.14 0.40	0.16 0.50	0.16 0.60	0.15 0.70	0.13 0.70
Windows	1	0.35 0.10	0.25 0.10	0.18 0.10	0.12 0.10	0.07 0.10	0.04 0.10
Altarpiece	0.9	0.14 0.20	0.10 0.24	0.06 0.28	0.08 0.32	0.10 0.36	0.10 0.40
Pendentives	0.8	0.12 0.30	0.10 0.40	0.08 0.50	0.06 0.60	0.06 0.70	0.06 0.70
Organ	0.8	0.12 0.20	0.14 0.24	0.16 0.28	0.16 0.32	0.16 0.36	0.16 0.40
Red marble	0.7	0.01 0.10	0.01 0.10	0.01 0.10	0.01 0.10	0.02 0.10	0.02 0.10
Wooden doors	0.6	0.14 0.12	0.10 0.13	0.06 0.14	0.08 0.15	0.10 0.16	0.10 0.17
Altar	0.1	0.03 0.12	0.04 0.13	0.11 0.14	0.17 0.15	0.24 0.16	0.35 0.17

Table 2 includes materials and coefficients used in simulation [2] [3] [4]. The most prevalent material is “stone” so it was the one used to calibrate the model. Besides, it has a high degree of uncertainty as standardized values do not include stone walls as the ones found in the basilica.

Simulation followed a tuning process based on the adjustment of the absorption coefficient of this material so the difference between measured and resulting T30 was below 5% (1JND). After the rest of parameters were compared and absorption and diffusion coefficients readjusted through an iterative process obtaining differences under 2 JND for average values of all parameters. The described procedure has been developed for the source located at the altar. After, we performed a simulation locating the source at the dome in order to verify the results obtained.

While adjusting and calibrating the worship model, we repeated the debugging and error correcting process in the "Misteri" model. In this case, coefficients from the worship model have been maintained using the grandstands and "cadafal" material to calibrate.

Adjusted and calibrated models have been modified introducing the audience and repeating simulations to detect the influence of the crowd in the basilica's acoustic behavior.

3 Results

Figure 3 shows the results obtained for the STI parameter for the 33 receiver positions included in simulation. Receivers in chapels have been excluded because they don't get direct sound. Intelligibility decreases as distance from the source increases, this effect is softened in the "Misteri" configuration. Also, it is clearly distinguishable that positions in the center of the nave provide better results than the lateral ones.

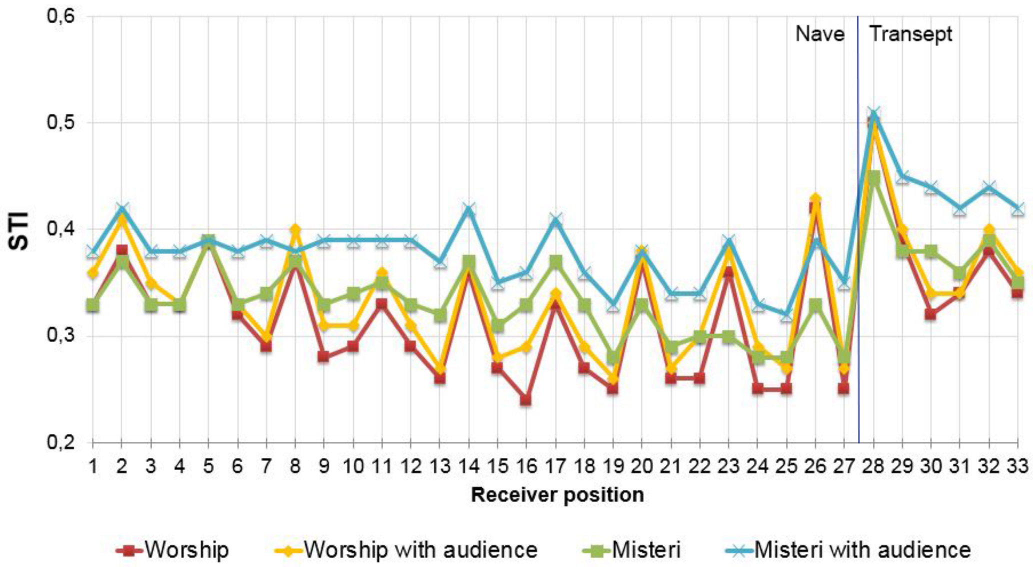


Figure 3: STI simulation results in each receiver position.

Figure 4 shows the simulation results for the most common uses of the basilica with audience and without it. Parameters studied include T30, EDT, C50, C80, Ts and G averaged by frequency.

Frequency variation follows the same trend in all the studied states.

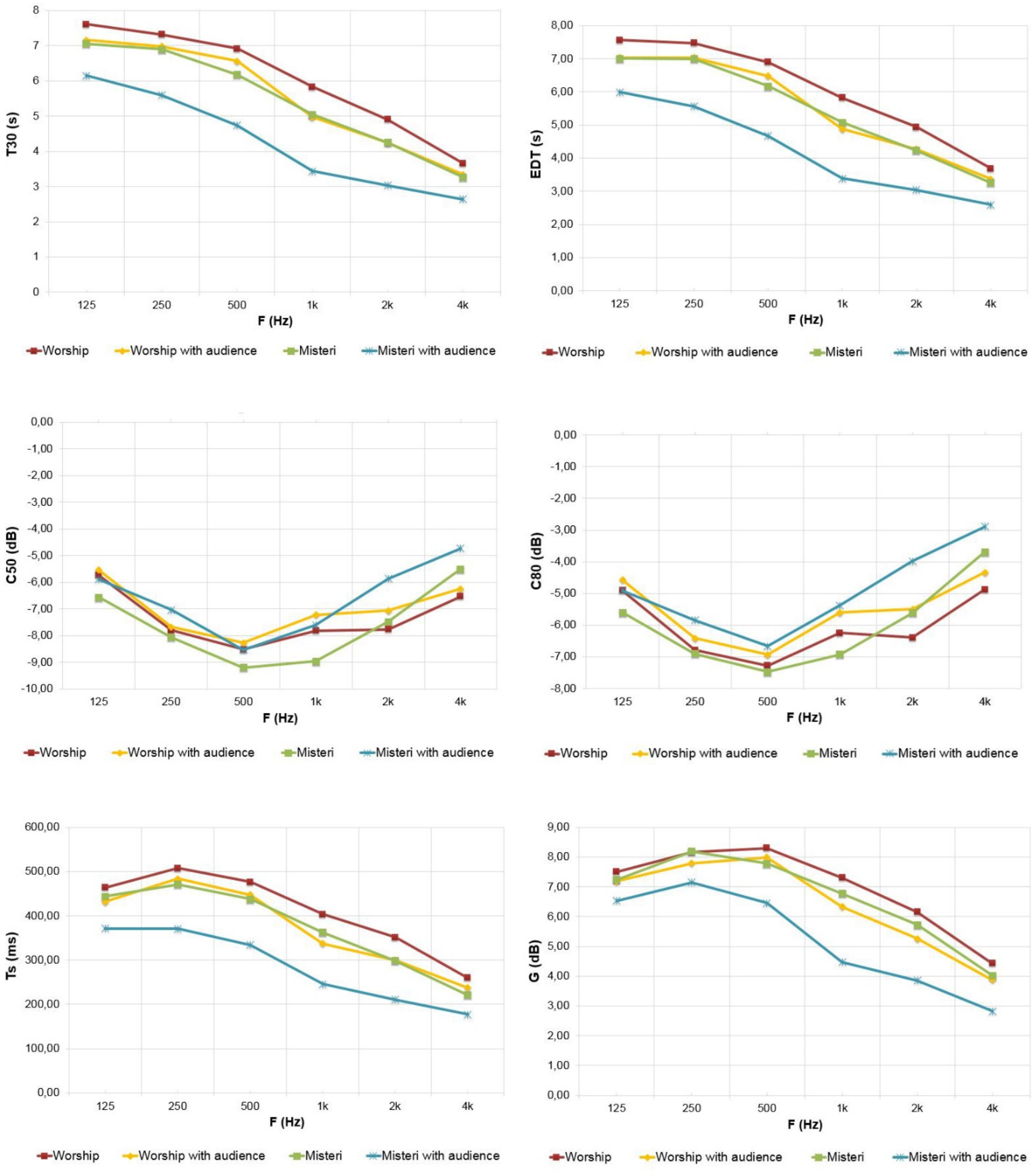


Figure 4: Simulation results. Parameters averaged by frequency.

The influence of the spatial changes introduced for the “Misteri” is noticeable since the results obtained for this configuration with empty space are very similar to those achieved for worship configuration including the audience.

Besides, the considerable increase of absorption due to the great affluence of public for the “Misteri” representation is clearly reflected in the graphs, since results for this situation present a significant reduction of reverberation and differ from the other three cases in T30, EDT, Ts and G parameters.

4 Conclusions

The analysis performed evidences that the Basilica has a different acoustic behavior when prepared for worship than it has during the “Misteri” theatrical representation. This is due to the inner space changes and the different amount of people that attends.

The study performed for parameter STI detected variations between the different parts of the basilica and also within the central and lateral positions in the nave. A detailed study of the rest of parameters should be accomplished in order to establish zonings and analyze the registered positions separately to propose the best acoustic enhancement measures. This will be possible because of the high number of positions registered.

Acknowledgments

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