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Influence of the configuration associated with the representation of the "Misteri" in the acoustics of the Basilica “Santa Maria d’Elx”

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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. In the case of the Basilica of Santa Maria, variations in the use of space are particularly important because 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.

For the theatrical performance of the "Misteri" the Basilica is transformed, modifying both the interior space, with the placement of a catafalque and various elements that are introduced to close the scene, and the number and distribution of people in it. In this paper we have carried out an analysis of the acoustic behavior of the temple for the configurations of worship and Misteri d’Elx from the measurements taken in both cases following ISO 3382.

Results show that the most remarkable differences between worship and representation correspond to energetic acoustic parameters (C50, C80, G), while parameters regarding intelligibility (STI), spatiality (IACCA) and RT30 as a temporal parameter are the most homogeneous, and hardly experience variation in the two configurations indicated. This occurs in all the areas and source positions studied. Changes in the mentioned parameters together with the greater absorption associated with to high occupation of the Basilica, make it an enclosure with a sonority very related to its use.

Keywords: Virtual Acoustics, Heritage, Simulation

1. INTRODUCTION

The present Basilica of Santa María 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. On 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 deambulatory. 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 deambulatory is opened to the central space throughout balconies.

For the “Misteri” representation some changes are introduced in the interior space of the Basilica. The dome is covered with a painted canvas representing the sky, the distribution of the furniture is modified, and wooden structures are placed in the nave and the crossing transept. Therefore, the geometric characteristics of the Basilica are different and volume decreases as shown in table 1, which affects the acoustic behavior of the room. The spatial changes introduced in the Basilica for the “Misteri” representation can be seen clearly in the models included in figure 1.

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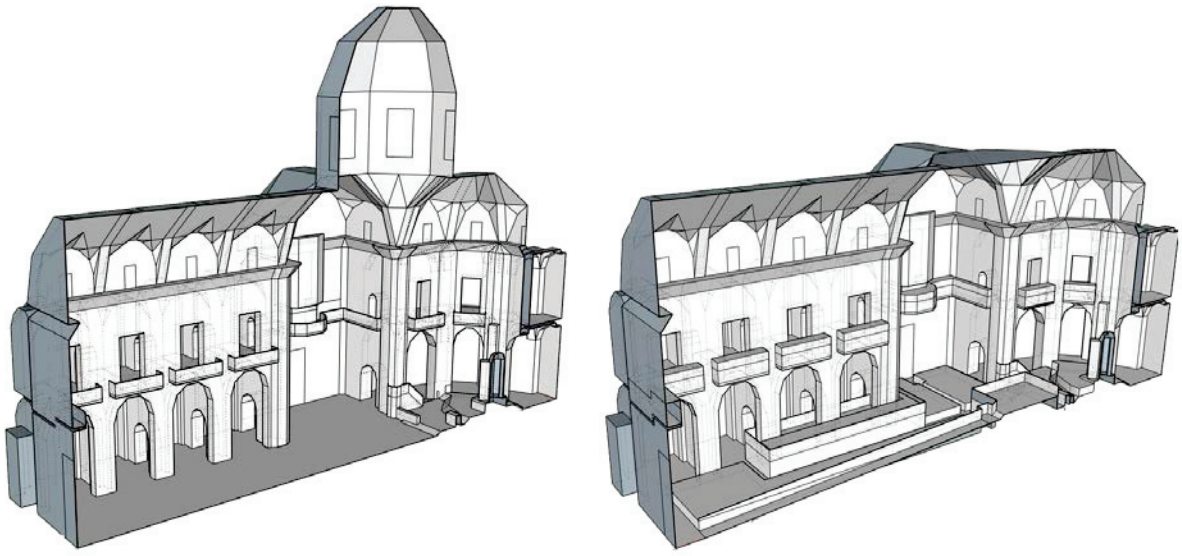

Figure 1. Virtual simplified models of the Basilica for worship and "Misteri" configurations.

Table 1. Geometric data of the Basilica

Worship configuration	"Misteri" Configuration
Volume: 25000 m^3	Volume: 22600 m^3
Nave height: 24 m	Nave height: 24 m
Crossing transept height: 40,80 m	Crossing transept height: 24 m

2. METHODS

In order to determine the acoustic behavior of the Basilica, two campaigns of measurements of acoustic parameters have been performed, corresponding to the configurations for worship and the representation of the "Misteri". Figure 2 shows two photographs taken during the measurement campaigns. The procedure followed has been the same in both cases varying only the number of positions registered. The protocol carried out was the one established by the international standard ISO 3382-1, which describes the measurement procedure including the measurement conditions and the minimum number of positions required as well as the equipment to be used (3).

Measurements have 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 multi-pattern microphone AT4050 / CM5 (frequency range: 20-20000 Hz, sensitivity: 15.8 mV, polar patterns: cardioid, omnidirectional, 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.

Figure 2. Measurement of acoustic parameters in the Basilica for both configurations.

ISO 3382 establishes that the measuring positions of both the source and the receivers must correspond with those of the natural sources and listeners respectively. For this reason, the measurements have been made with two significant source positions resembling the two main uses. We placed one source in the altar to simulate the priest during worship and the other in the center of the dome where most of the representation of the "Misteri" takes place.

37 positions have been registered in the campaign carried out with the Basilica configured for the cult. In the case of the "Misteri" the number of registered points ascends to 86 and they were distributed between the ground floor, including the apse, the deambulatory, and the balconies, since they are also occupied by the audience. Table 2 shows the number of receiver positions and their distribution registered for each configuration.

Table 2 - Receiver positions measured for both configurations and their distribution inside the Basilica.

Zone	Worship configuration	"Misteri" Configuration
Nave	27	27
Transept	6	12
Chapels	4	8
Wood grandstands	-	12
Apse	-	4
Deambulatory	-	2
Balconies	-	21

In order to acoustically characterize the Basilica of Santa Maria, some parameters have been selected. These are associated with the main subjective qualities of the rooms. Following previous research (4), the parameters studied have been classified into four groups:

- Reverberation parameters: reverberation time for 30dB of decay (RT)
- Energy parameters: speech clarity (C50), musical clarity (C80) and sound force (G)
- Spaxiousness parameters: interaural cross-correlation index (IACC)
- Parameters of intelligibility: word transmission index (STI).

Results have been analyzed in terms of real value but also in terms of perception using the JND (just noticeable difference) values defined in ISO 3382.

3. RESULTS

By way of illustration summary, Figure 3 shows the mean values per frequencies of some of the parameters studied. It is observed that influence of the configuration of the Basilica for the representation of the "Misteri" differs in each parameter, these differences are analyzed in detail in the following points.

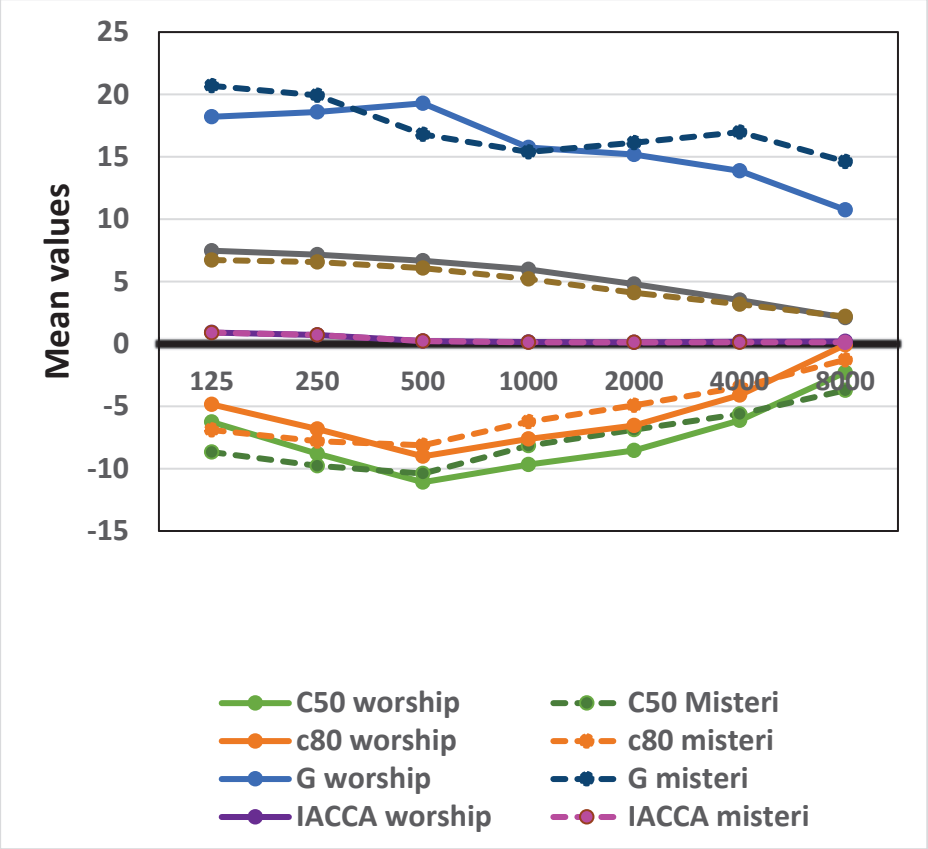

Figure 3 – Mean values of parameters measured for both configurations

3.1 Reverberation parameter: RT

Table 3 – RT mean values measured for both configurations. Real and perceptive differences between them.

Frequency	Worship	"Misteri"	Dif. (s)	Dif. (JND)
125	7,471	6,725	0,747	2,00
250	7,154	6,572	0,582	1,63
500	6,673	6,086	0,587	1,76
1K	5,976	5,200	0,776	2,60
2K	4,799	4,112	0,687	2,86
4K	3,505	3,166	0,338	1,93
8K	2,105	2,191	-,086	0,82

Table 3 collects the mean values of the reverberation time in the temple obtained in both cases. In terms of real value, the decrease in the reverberation time of the room that is caused by the effect of the adaptation for the representation is not high and it does not reach the second in any case. The highest difference rises to 0.78 seconds at 1000 Hz. In terms of perception, the differences are noticeable in all frequencies, except at 8000 Hz.

3.2 Energetic parameters: C50, C80 and G

Table 4 – C50 mean values measured for both configurations. Real and perceptive differences between them.

Frequency	Worship	"Misteri"	Dif. (dB)	Dif. (JND)
125	-6,261	-8,667	2,406	1,60
250	-8,795	-9,775	0,980	0,65
500	-11,089	-10,394	-0,695	0,46
1K	-9,662	-8,166	-1,496	1,00
2K	-8,547	-6,885	-1,662	1,11
4K	-6,123	-5,628	-0,495	0,33
8K	-2,291	-3,721	1,429	0,95

Table 4 shows the comparison between the mean values in the church for parameter C50. As the frequency increases the average values of C 50 decrease for both configurations. However, this trend is reversed from 1000 Hz and mean values are increased again. As it can be seen, the greatest difference is observed at 125 Hz, reaching 2.4 dB. In terms of perception, there is practically no difference for this parameter since the value of 1 JND is exceeded only in two cases and by very little.

Table 5 – C80 mean values measured for both configurations. Real and perceptive differences between them.

Frequency	Worship	"Misteri"	Dif. (dB)	Dif. (JND)
125	-4,850	-6,899	2,049	1,37
250	-6,819	-7,800	0,981	0,65
500	-9,016	-8,127	-0,888	0,59
1K	-7,632	-6,237	-1,395	0,93
2K	-6,554	-4,918	-1,636	1,09
4K	-4,103	-3,473	-0,630	0,42
8K	-0,080	-1,277	1,197	0,80

Mean values of the parameters in the church included in Table 5 show that at low frequencies the Basilica behaves slightly better in worship configuration. However, the opposite occurs at medium-high frequencies. As in the previous case, the greater variations between average values are found at 125, 1000 and 2000 Hz, and they do not exceed 2 dB. In terms of perception, it can be considered that there is no difference since the value of 1 JND is slightly exceeded only in two cases, without approaching to 1.5 JND.

Table 6 – G mean values measured for both configurations. Real and perceptive differences between them.

Frequency	Worship	"Misteri"	Dif. (dB)	Dif. (JND)
125	18,202	20,689	-2,487	2,49
250	18,600	19,940	-1,340	1,34
500	19,291	16,788	2,503	2,50
1K	15,737	15,380	0,357	0,36
2K	15,171	16,122	-0,951	0,95
4K	13,865	16,978	-3,113	3,11
8K	10,756	14,620	-3,865	3,86

Table 6 shows the mean values in the room and the differences registered in parameter G. The greatest variations are found at extreme frequencies, with values of 2.5 and 3.8 dB. At the most representative frequencies results are varied, having a significant variation of 2.5 dB at 500 Hz meanwhile at 1000 Hz values differ only 0.3 dB.

There is no difference in terms of perception at 1000 and 2000 Hz, however it amounts to 2.5 JND at 500 Hz and surpasses 3 JND at high frequencies.

3.3 Spaciousness parameter: IACCA

Table 7 – IACCA mean values measured for both configurations. Real and perceptive differences between them.

Frequency	Worship	"Misteri"	Difference	Dif. JND
125	0,911	0,907	0,004	0,05
250	0,707	0,716	-0,010	0,12
500	0,219	0,238	-0,018	0,23
1K	0,141	0,124	0,017	0,21
2K	0,121	0,119	0,002	0,03
4K	0,165	0,119	0,045	0,56
8K	0,197	0,125	0,072	0,90

Table 7 shows the differences in mean room values of the IACCA parameter. The differences are minimal, the highest are given at high frequencies but do not exceed the value of 0.072. In terms of perception, there is no difference between one configuration and another.

3.4 Intelligibility parameter: STI

Table 8 – STI mean values measured for both configurations and difference between them.

Worship	"Misteri"	Difference
0,328	0,333	-0,005

Table 8 includes the mean STI values in the temple for both uses and the differences between them.

When comparing the mean values in the room, the difference is minimal so it can be considered that the spatial changes do not have an influence on STI parameter.

4. CONCLUSIONS

The differences between the Basilica configuration for worship and the one for the "Misteri" representation have been studied throughout the analysis of several acoustics parameters measured in situ. The measurements how they affect the spatial changes. The analysis carried out shows the influence of the spatial changes introduced and how the basilica has a different acoustic behavior when it is prepared for the worship and during the theatrical performance.

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