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ACOUSTICAL CHARACTERIZATION OF LIVE MUSIC AND SINGING IN NOSSA SENHORA DO PILAR CHURCH, GOA

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Abstract

This case study was conducted at the church of Nossa Senhora do Pilar, Goa and is part of a series of tests to gauge the acoustical difference in this 400 year old church from a pre-restoration phase to the post-restoration phase. The worship space was acoustical characterized using objective acoustical parameters (*RASTI, RT, D50, C80, TS,* and *LAeq*) and subjective acoustical impressions of listeners for live performances of sacred music and sacred singing. Solo performances on stringed and blowing instruments were compared with solo voice recitals. A choral group with and without accompaniment was also tested. Two different performance locations in the worship space were tested for ensemble music and for choir singing. Amongst the significant results, the choir loft source location registered a 89% better L_{Aeq} value and 80% better RASTI value than the nave floor source location. Amongst the subjective acoustical results, *ACII* ($p = 0.15$), *SSaF* ($p = 0.06$) and *SInF* ($p = 0.18$) for sacred singing by the choir with an accompanying ensemble showed significantly better results at the choir loft location than at the nave floor location. The values of the objective acoustical parameters obtained in this survey were compared with those obtained earlier, so as to gauge the impact of the restorative exercises (so far) undertaken in the church. RT, RASTI, D50 and C80 values showed improvement. This study thus adds on to a comparative explanation of the restoration of the acoustical heritage of Nossa Senhora do Pilar church.

Key Words: Subjective Acoustic Impressions, Objective Acoustical Parameters, Acoustical Comfort Impression, Acoustical Worship Indices, Restoration.

1. INTRODUCTION

A worship Space invites a devotee to be spiritually animated and to experience indepth tranquility. Good Acoustical Sacred Heritage in a church enables a liturgical celebration within, to create an 'Active, Conscious and a Total Experience' of the Divine [A]. This paper is a part of a process to monitor the variations in the acoustical sacred heritage of Nossa Senhora do Pilar church [B][C] in Goa as it goes through the process of restoration. The earlier studies on this church have expounded the subjective and the objective acoustical parameters either before the restoration was undertaken or during the earlier stage of the restorative interventions [D][E][F]. This study is situated during a later stage of restoration when the new lime render was already applied to the walls of the church. The different stages of the restoration (so far) are depicted in Figure 1.

FIGURE 1: (A) The exterior look of Nossa Senhora do Pilar church during an earlier stage of restoration. (B) The exterior look of Nossa Senhora do Pilar church during a later stage of restoration. (C) The interior look of Nossa Senhora do Pilar church during an earlier stage of restoration. (D) The interior look of Nossa Senhora do Pilar church during a later stage of restoration.

While the pre-restoration subjective tests evaluated the impact of the variation in the musical source and the musical type on the subjective acoustical comfort of a listener, this study goes a little further to compare the impact of a solo voice recital with that of a solo musical instrument rendition and to compare the musical performances of a choir group with and

without an accompaniment. The variations from different sources are evaluated through a comparison of derived acoustical parameters [E][F][G][H].

2. METHODOLOGY

The choir loft location of the church and the nave floor choir location were chosen as Music Source positions 'MA' (Nave floor) and 'MB' (Choir Loft floor) respectively. Objective acoustical tests were obtained for 'MA' & 'MB' and recorded at twelve different locations as shown in Figure 3.

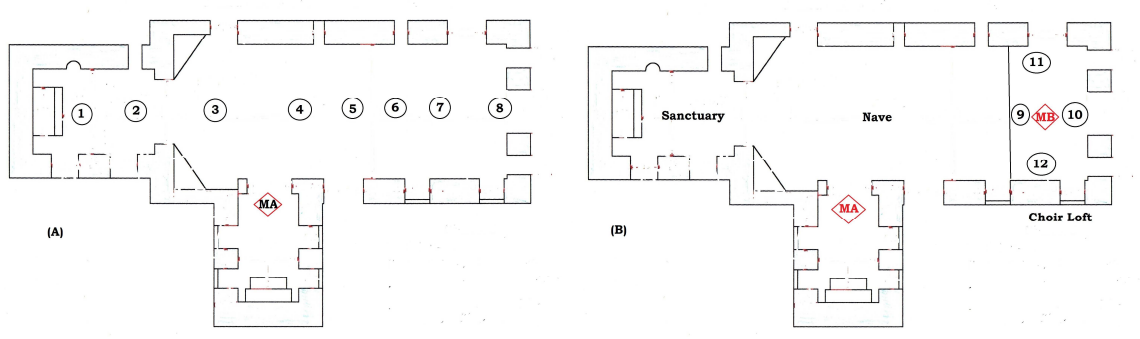

FIGURE 2: (A) Recording locations (1-8) on the nave floor for the impulse response tests and the source location (MA) on the nave floor.
(B) Recording locations (9-12) on the choir loft floor for the impulse response tests; Source location (MA) on the nave floor and Source location (MB) on the choir loft floor.

Impulse Response tests were conducted in compliance with the ISO-3382 standard [I]. and objective acoustical parameters such as [Noise Ambience (L_{eq}), Reverberation Time (RT), Loudness (G), Rapid Speech Transmission Index (RASTI), Energy Time Graph (ETG) Definition (D_{50}), Clarity (C_{80}) and Centre time (TS) were measured using the laptop based ARTA software.

Solo performances on violin, mandolin and clarinet were compared with solo voice recitals. A choral group with and without accompaniment was also tested. Two different music source positions were tested for ensemble music and for choir singing. 25 listeners, mainly post-graduate college students, were deliberately chosen from amongst non-church goers. They were trained to make their subjective acoustical preferences according to the acoustical traits enlisted in the scoresheets and seated spatially on the floor of the sanctuary, nave and the choir loft. The performers were regular church choir members, accustomed to playing sacred music and singing in churches. The impact of the church, as a performance space, on listeners was deduced from the recorded subjective acoustical impressions in terms of induced reverential awe, sacred intelligibility and sacred liturgical silence using derived Acoustical Comfort Impression Index (ACII) and subjective Acoustical Worship Indices (AWI) such as

Subjective Sacred Factor (SSaF), Subjective Intelligibility Factor (SInF) and Subjective Silence Factor (SSiF) [E][F].

3. RESULTS & DISCUSSION

The observed variance of different objective acoustical parameters for two different music sources (MA - Floor of the Nave) (MB - Floor of the Choir Loft) as recorded at twelve different locations in the church is shown in Figure 3.

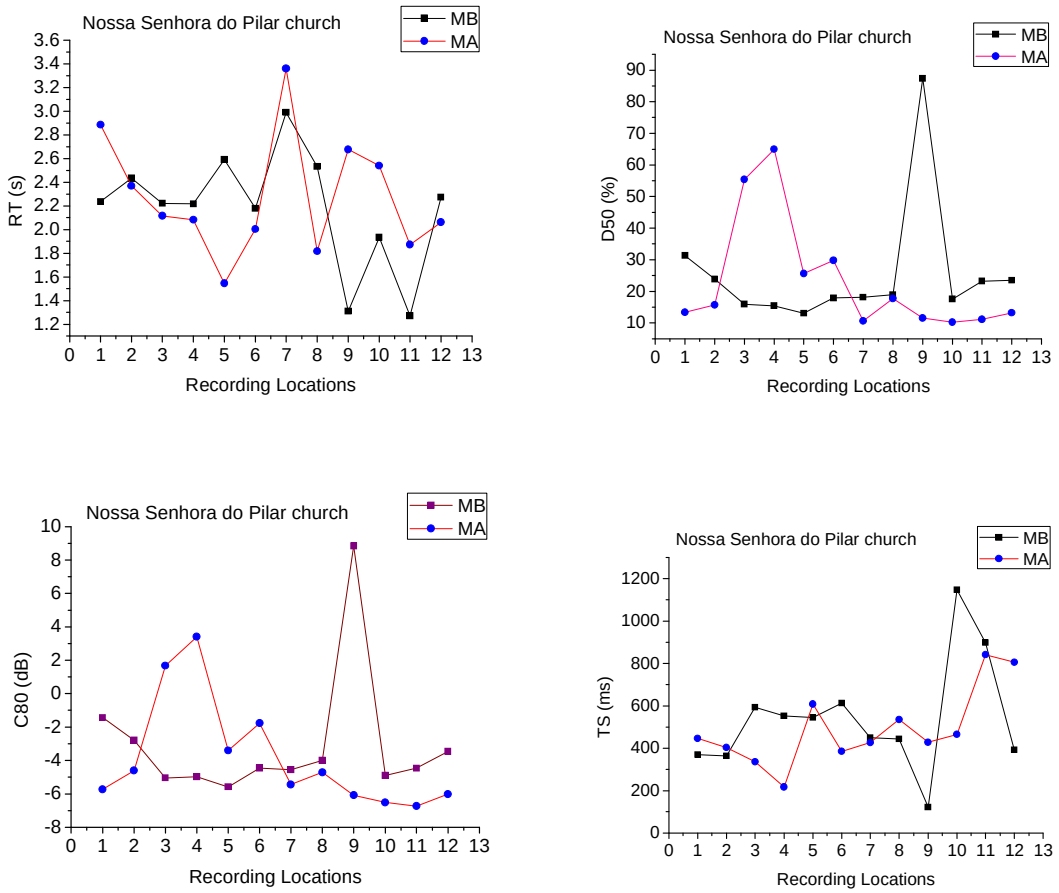

Figure 3: The variance of RT, D50, C80 and TS at twelve different locations for MA & MB

Although the average values of populations of all objective acoustical parameters were tested, only L_{Aeq} and RASTI showed greater than 80% significant differences in their respective means. The significant objective acoustical parameters are enlisted in Table 1.

Table 1. ANOVA tests on means of reasonably significant objective acoustical parameter populations in the church (averaged across twelve recording locations in the church)

Acoustical Parameter	Source Location	Mean	p value
L_{Aeq}	MA Floor of the Nave	77dB	0.11
	MB Floor of the Choir Loft	89 dB	
RASTI	MA Floor of the Nave	0.32	0.20
	MB Floor of the Choir Loft	0.38	

The means of ACII and the AWI for the music rendered by the choir accompanied by the ensemble, yielded some significant differences between the two music sources as reflected in Table 2. The solo performances either through human voice or through music rendition by the clarinet, violin and mandolin did not show any significant difference in their respective subjective scores.

Table 2. ANOVA tests on means of reasonably significant subjective AWI populations for the choir accompanied by the ensemble (averaged across 25 listener locations in the church) from 2 different music source positions

Acoustical Parameter	Source Location	Mean	p value
ACII (Choir + Ensemble)	MA Nave floor	0.80	0.15
	MB Floor of the Choir Loft	0.74	
SSaF (Choir + Ensemble)	MA Nave floor	0.78	0.06
	MB Floor of the Choir Loft	0.70	
SInF (Choir + Ensemble)	MA Nave floor	0.81	0.18
	MB Floor of the Choir Loft	0.74	

The objective acoustical parameters obtained through tests conducted in the pre-restoration era were compared with those obtained during the process of restoration. The comparison of these values is showcased in Table 3. However, the sources were different in these two different rounds of tests.

Table 3. Comparison of objective acoustical results in Nossa Senhora do Pilar church.

Stages	RT (s)	D50 (0-1)	C80 (dB)	TS (ms)	RASTI (0-1)
Pre-Restoration	3.01	0.21	-3.75	250	0.35
During Restoration	2.23	0.24	-3.45	516	0.35

4. CONCLUSIONS

The following conclusions can be drawn from results presented above:

- The area at the back of the nave, just beneath the edge of the choir loft, perceives a longer decay time (RT) for both the source locations (cf. Figure 3).
- Except for locations directly in front of the sound source, Definition for speech (D50) and Clarity for music (C80, TS) are found to be low in the church (cf. Figure 3).
- The impulse from the choir loft (MB) is found to generate a louder response (LAeq) and better speech intelligibility (RASTI) in the church than the impulse from the nave floor (MA).(cf. Table 1)
- Although, choral recital (without accompaniment) and music rendition by an ensemble of violin, mandolin and clarinet, were also done, it was only the choral recital accompaniment by the ensemble that showed a significant difference between the two

locations of performance (MA & MB). The means of SSaF show the nave floor (MA) to be 94% significantly better than the choir loft (MB) ($p = 0.06$). The scores of ACII show 85% significant difference and the scores of SInF indicate 82% significant difference between the two sources in favour of the nave floor (MA) (cf. Table 2). This implies that choir singing backed by an ensemble, would deliver a better impact (in terms of acoustical comfort, reverential awe and sacred intelligibility) when performed from the floor of the nave (MA) than from the floor of the choir loft (MB).

- No significant difference were found among the means of the subjective scores for any of the solo performances from the floor of the nave (MA), indicating that there is no subjective reason to prefer a solo voice recital or a solo rendition on violin, mandolin and clarinet at 'MA'.

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