# CONVERSION OF JORDÃO'S THEATRE HALL INTO A MULTIPURPOSE HALL – STUDY OF ITS ACOUSTICAL PROPERTIES

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## ABSTRACT

The aim of the work presented on this paper is to characterize Jordão's Theatre Hall acoustical performance, in order to study the ability for its conversion into a Multipurpose Hall.

This paper is based on a study of the acoustical rehabilitation of Jordão's Theatre Hall at Guimarães, Portugal. Built in 1938, this theatre (actually dismissed) is an example of the combination of the earliest art deco of Portuguese architecture with several geometric influences of Italian Opera Houses. The main Hall has a rectangular configuration. The audience area (with a capacity for 1220 spectators) has a volume of 5632 m3, distributed by two-order levels of seats.

This characterization is done as follows:

- Acoustical measurements of Reverberation Time and RASTI *in situ*;
- Computation of the Hall using E.A.S.E. 3.0 software, which provides the acoustical performance of the represented theatre configuration based on specific acoustical parameters.

## RESUMO

O trabalho apresentado neste artigo, tem como objectivo a análise da performance acústica do Teatro Jordão, de modo a desenvolver futuros estudo da sua capacidade de um pavilhão multi-usos. Este artigo é baseado num estudo de reabilitação acústica do Teatro Jordão em Guimarães, Portugal, construído em 1938. Este Teatro (desactivado na actualidade) é um exemplo da combinação das primeiras fases da arte deco, da arquitectura Portuguesa, com várias influências geométricas das casas de Teatro Italianas. A sala principal tem uma configuração rectangular. A zona da plateia (com capacidade para 1220 pessoas) tem um volume de 5632 m3, distribuídos por duas zonas de cadeiras desniveladas.

O estudo foi baseado em duas vertentes:

- Medição do Tempo de Reverberação e do RASTI *in-situ*,
- e nos resultados da simulação do modelo computorizado da sala, executada no Software E.A.S.E. 3.0, a qual fornece a performance acústica da configuração representado do teatro, baseada em parâmetros acústicos específicos.

1. INTRODUCTION

By the request of Mr. Bernardino Jordão, the Architect and Civil Engeneer Júlio José M. Brito designed Jordão´s Theatre, in 1937.

Although of being the only Theatre Hall in the city of Guimarães, this example of art deco architecture it is actually dismissed and almost in ruins.

The main Hall, with an audience area volume of 5632m3, has 17,70m of width, 29,60m of length and a maximum height of 11,00m.

Throughout the years were carried out in this Theatre several kinds of shows: drama, ballet and musical performances. By the early sixties another performance attracted the audience: the cinema.

In the first visit that took place by the authors to the Theatre brought out two different kinds of feelings: at first, it was very disappointing watching a building with this importance becoming a ruin, and secondly the idea of it's acoustical rehabilitation was considered unanimously as an attractive challenge.

## 2. INSTRUMENTATION AND METHODOLOGY

The study adopted was based on:

- Acoustical measurements of Reverberation Time made *in situ*;
- A computerized model of the Hall, using E.A.S.E. 3.0 software program and the acoustical performance simulation of the present configuration according to the following parameters: Reverberation time, Clarity (C50 and C80), RASTI and ALCons.

It was possible to find out several differences between the first designed Hall and the one that was built, leading these differences into a continuous correction process.

For the measurements, the sound source was located in the center of the stage, in order to reproduce the most common location of performers. At the same time there were selected ten different points in the Hall, simulating the position of several spectators.

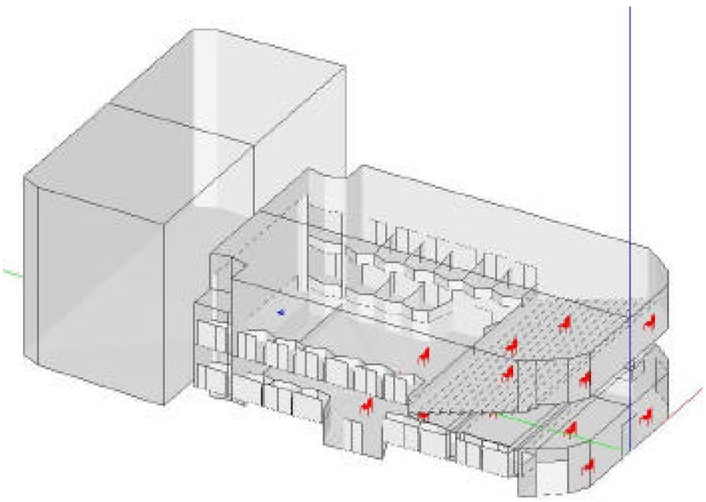


Figure 1. The final version of the reproduced Hall

## 2.1. Acoustical Parameters

As the final objective of the work is to purpose solutions of acoustical correction, which can convert the Theatre into a Multipurpose Hall, it is considered essential the study of its acoustical performance according to two main objectives: by improving hearing quality, assure the correct intelligibility of words and sound, and at the same time, guarantee good levels of acoustical comfort.

In order to reach the objectives refereed above, it was a central issue to establish a number of parameters that could evaluate the actual behaviour of the Hall. The parameters that were considered relevant in this case were: Reverberation time, Clarity (C50 and C80), RASTI and ALCons.

## 2.2. Reverberation Time

This parameter conditions the level intelligibility of words and the quality of listening music within a Hall.

The next figure and table shows the results obtained both by simulation using the computer model and those obtained with the *in situ* measurement.

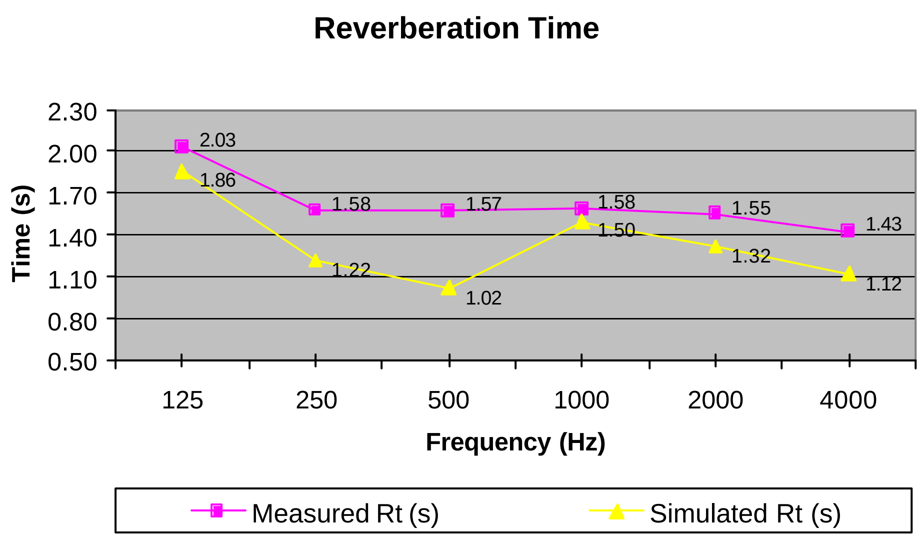



Figure 2. Graphic with the estimated reverberation time of the Hall (s)

| **Freq.** (Hz) | **Measured Rt** (s) | **Simulated Rt** (s) |
|---|---|---|
| **125** | 2.03 | 1.86 |
| **250** | 1.58 | 1.22 |
| **500** | 1.57 | 1.02 |
| **1000** | 1.58 | 1.50 |
| **2000** | 1.55 | 1.32 |
| **4000** | 1.43 | 1.12 |

**Table 1**. Estimated reverberation time of the Hall (s)

It is possible to observe, comparing the reverberation time obtained on the measurements made *in situ* and those obtained on the computer simulation, that the differences are not very significant. However between the values of 250 and 500 Hz some disparity is still detected.

Analysing the results, according to the studies published by numerous authors, we can conclude that the reverberation time of this room is not the most indicated:

- For speech: the results obtained in 500 and 1000Hz were quite higher than the ideal – the optimum Rt for a room with this area would be between 0.5 and 1.0 for 500Hz and 1.0 for 1000 Hz;
- For music: in this kind of performance witch the acoustical requests varies form chamber music to church music, with quite different indicated Rt, the opinion of several authors is also very diffuse. However, it is possible to observe that the results obtained are closer to the ones requested by *clear melodies* (chamber music, jazz and even opera) than to ones with more *involving melodies* (church or romantic music).

## 2.3. RASTI (Rapid Speech Transmission Index)

RASTI is a method of quantifying the intelligibility of transmitted speech and is based on the method of the Speech Transmission Index (STI). If the value is 0 it means that the temporal speech envelope at the listener's position is very different from the speech envelope at the speaker's mouth = no intelligibility. If the value is 1 it means that the intelligibility of the spoken word is perfect.

The next image simulates different areas of speech intelligibility in the room, according to the RASTI acoustical parameter.

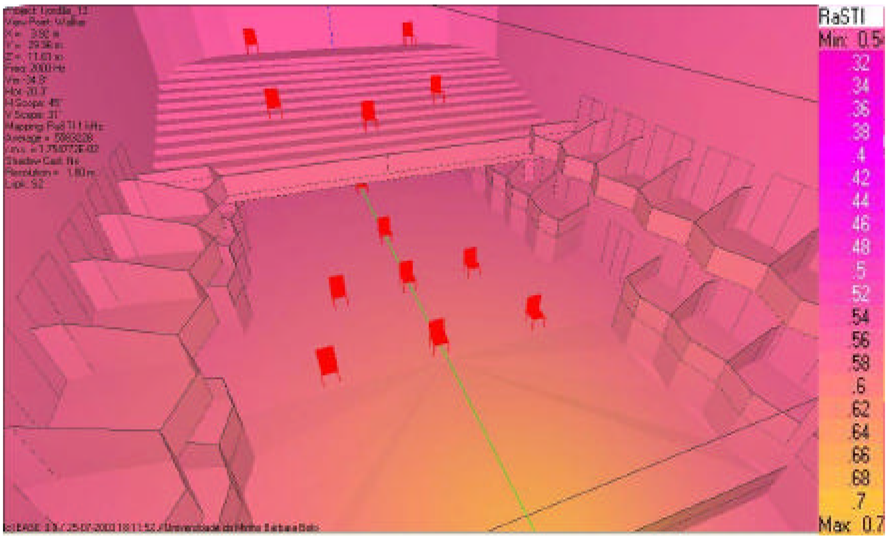



Figure 5. Estimated RASTI

As the figure 6 shows, the values obtained by computer simulation are between 0.54 and 0.70 - this means that the intelligibility of sound in the room is considered reasonable.

The next table compares the values of RASTI obtained on the ten points selected in the room, both by measurement *in situ* and by computer simulation.

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Measured RASTI** | 0.58 | 0.55 | 0.53 | 0.52 | 0.53 | 0.54 | 0.58 | 0.56 | 0.53 | 0.59 |
| **Simulated RASTI** | 0.61 | 0.59 | 0.57 | 0.60 | 0.59 | 0.55 | 0.55 | 0.56 | 0.56 | 0.55 |

**Table 2**. Estimated RASTI of the Hall.

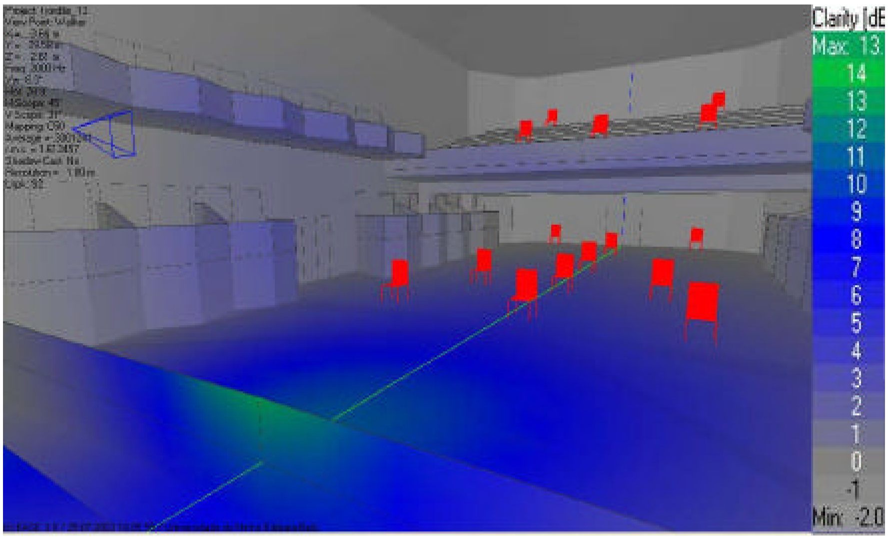
As it is possible to observe the results obtained by measurement are very similar to the ones got from computer simulation. As it was observed before, although they are far from excellence, these values are considered fair.

## 2.4. Clarity (C50)

Clarity is the ratio of energy before and after a certain split of time in decibels. This is the definition of ratio between energy arriving before and after 50 milliseconds, in decibels. This parameter is used to evaluate intelligibility of the spoken word.

Any value above 0 dB in a standard room allows good speech intelligibility. And any value above -5 dB in a more reverberant than normal room allows good speech intelligibility of the sound source.

The following figure illustrates the areas of the room with different C50 values.




Figures 6. Estimated C50

As the figure shows, the values presented in almost every regions of the room are considered acceptable.

## 2.5. Clarity (C80)

This is the definition of ratio between energy arriving before and after 80 milliseconds, in decibels. This parameter is used to predict the articulation of different modes of music. This articulation is dependent upon the speed of the music, the type of instrument and the reverberation time of the room.

As the different existing kinds of music performance have different acoustical requests, we can say that any value between -2 dB and 8 dB is considered acceptable:

- Between -2 and 2 dB is good for organ or blown instruments;
- Between 0 and 4 dB is good for bowed instruments;
- Between 2 and 6 dB is ideal for plucked instruments;
- Between 4 and 8 dB is ideal for percussive instruments;

It is possible to observe, in figure 7, the dark grey/blue areas (corresponding to values among 0 and 8 dB) are very reduced and the regions with light grey coloration (matching with very low values) are represented in almost every surfaces of the room.

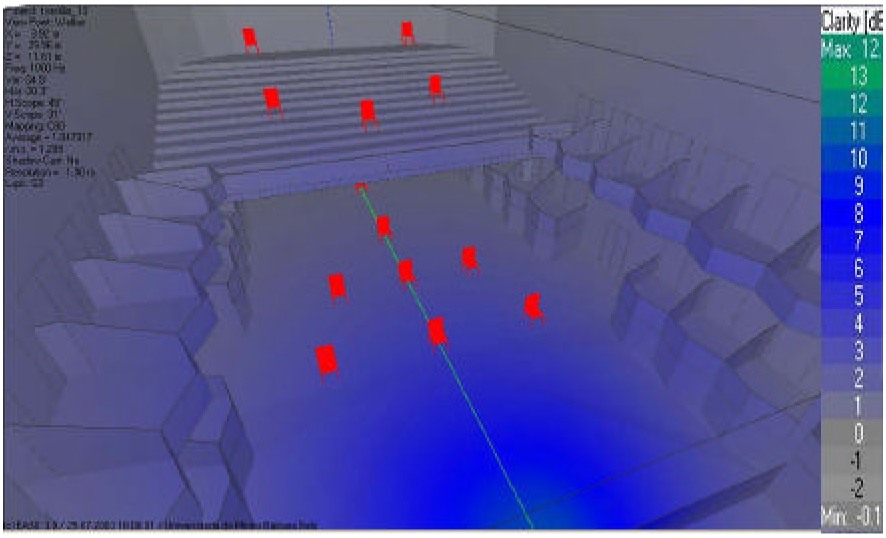



Figure 7. Estimated C80

## 2.6. ALCons (Articulation Loss of Consonants)

Measured in percentage, this parameter evaluates the loss of intelligibility of the consonants on speech. 100% means that 0% of the consonants articulated were understood, and an ALCons of 0% signifies that the spoken word was fully comprehended.
The next figure shows the areas of the room corresponding to different ALCons values at 2000 Hz, which is generally considered the frequency band with most contribution to speech understanding.

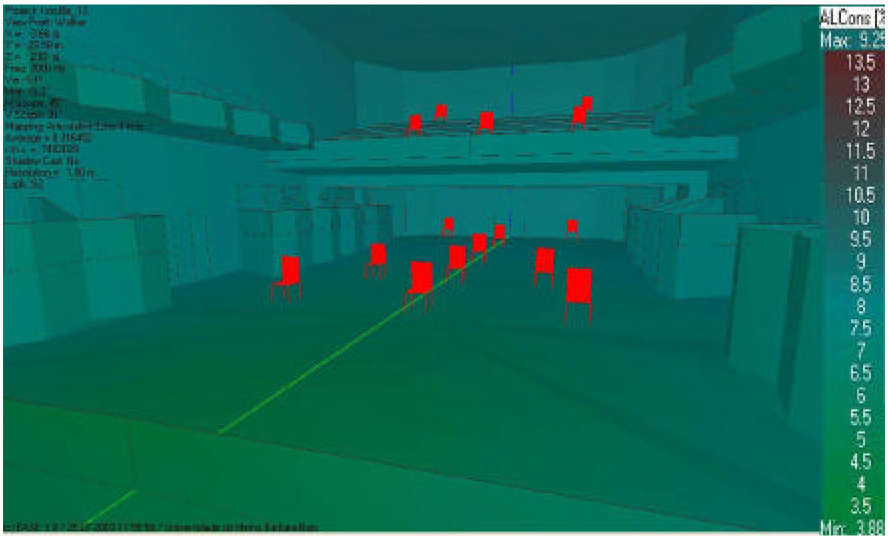



Figure 8. Estimated %ALCONS

As the image shows the green/blue surfaces (corresponding to a fair intelligibility of speech) is represented in almost every regions of the room and, alike those observed on the RASTI and C50 figures.

## 3. CONCLUSIONS

Analysing the test results it is possible to conclude that the listening quality of the Hall is considered fair, both for speech and for music performances.

The next step of this work is to improve the computerized model, in order to achieve the best accuracy between computer simulation data and the results obtained *in situ.*

Therefore it is intended, in a close future, to point out some solutions of acoustical correction that can improve the ability of the theatre to perform both speech and music (theatre plays, opera and instrumental performances). This acoustical correction will be made by the re-designing of the Hall's geometry and by the use of new surface materials, with the best compromise between architecture and acoustics, creating a changeable system which can be adapted depending on the kind of performance solicitation of the Hall.

## REFERENCES


1. Arau, Higini, "ABC de la acústica arquitectónica", Barcelona, 1999.
2. Daumal Domenèch, Francesc, "Acústica arquitecónica en grans sales", Barcelona 1986.
3. Isbert, Antoni Carrión, "Diseño acústico de espacios aruqitectónicos", Barcelona 1998.
4. Kutruff, Heinrich, "Room acoustics", 1991.
5. Recuero Lopez, Manuel, "Acústica Arquitectónica", 1993.
6. Sendra, J. J., T. Zamarreño, J. Navarro, "La acústica de las iglesias gótico-mudejares de Sevilla", Sevilla 1999, pp. 23-32.
7. Patricio, J. "Acústica nos Edificios", Ed. do autor, Lisboa 2003.