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Acoustic Studies of a Neoclassical Museum Through simulations in a three-dimensional model

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ABSTRACT

Museums are buildings of historical, architectural and educational value. Characterizing them acoustically provides design grants related to the acoustical comfort of users delivering quality to these buildings. The activities developed in a building direct the needs program, so the technical knowledge of the variables that involve a project is of fundamental importance to the designer because it gives freedom of manipulation of the project so that the desired acoustic comfort is reached. This work deals with acoustic studies of *Pinacoteca de São Paulo*, located in the city of São Paulo, Brazil. It is a museum of visual arts with an emphasis on Brazilian production from the nineteenth century to the present day. The neoclassical building was designed at the end of the 19th century by the architect Ramos de Azevedo, where it initially housed the *Lyceum of Arts and Crafts* (School) and is listed as a state historic patrimony. In the late 1990s he underwent a renovation project led by the architect Paulo Mendes da Rocha. The acoustic studies were performed through simulation of the three-dimensional model in computational software with comparisons between source position and microphones. This work is part of a PhD research that is underway.

Keywords: Room Acoustics, Museum, Simulation

1. INTRODUCTION

An architecture design involves the knowledge of variables of essential importance for a satisfactory and quality result. The main activities developed in a building will demand a specific acoustic comfort program. In museums, the main activity is that of observation and introspection, so that the interaction between people occurs between small groups.

This work deals with the needs related to museum acoustics - buildings that are of interest for room acoustics, but which are not of critical audience. This work presents acoustic studies of the Pinacoteca of São Paulo, which has neoclassic architecture. The results were obtained from acoustical simulations in a three-dimensional model. This study is an initial part of a PhD research that is under development.

Acoustic parameters were evaluated, such as: Reverberation Time (RT), Early Decay Time (EDT), and Definition (D50).

The Early Decay Time (EDT) analyzes the initial decay, using the first 10 dB of decay of the SPL. This parameter has a strong relation with the reverberation perception of the listeners in the room.

The Definition (D50) index is the parameter that provides clues related to speech comprehension. It is defined as the energy ratio of the impulsive response that reaches the listener in the first 50 ms and the energy from the 0 ms to its end (in linear scale). The D50 parameter have typical values indicated at the standard ISO 3382:2009 [1], related to the average between 500 and 1000 Hz. For the Definition (D50), the standard consider acceptable if it lies from 0,3 to 0,7 [1].

The well-being of museum visitors is an important condition in these buildings. This includes the acoustic comfort, which is a qualifying and indispensable item. It is necessary to note that the experience of visitors involves attributes that go beyond formal, geometric and aesthetic issues [2]. Jónsdóttir [3] presented the study of three Danish museums regarding Reverberation Time, Background Noise and Speech Transmission Index (STI). The author used computer simulations and interviews. In addition, an analysis was made of the relationship between the STI and the privacy of speech. It was observed that there is a need for strict concerns regarding the privacy of discourse in

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museums. The need for privacy of speech was also pointed out in studies carried out in the Serralves Museum, Portugal [4,5], since the very concept of museum induces an intimate and private environment. There must be balance between privacy and intelligibility, items that have opposite acoustical needs, but which are essential for the acoustic quality of museums. There is a consensus regarding the shortage of scientific work involving museum acoustics.

The relevance of the modeling and optimization tools in the design process, as well as the manipulation of the architectural elements in the preliminary study phase, provides support in the search for solutions in buildings, especially with large volumes. The process of digital manipulation and creation of surfaces is like a work of craftsman, where the professional "sculpts" the materials with the security of obtaining the desired acoustic characteristics of the room. The parameterization between geometry and acoustics also provides the possibility of developing solutions with shapes adequate for an architectural style. This is especially important in works of restoration and revitalization of buildings, integrating acoustics with architecture [6].

The development of three-dimensional modeling tools provides a more intuitive and interactive design process, giving the ability to shape the spaces with a good understanding of the sound behavior in the environment. The use of computational tools enriches acoustic quality of buildings. It is possible to reconstruct scenarios of the past, in order to study the conditions of the building, and to plan, manipulate and design buildings with the acoustic solutions already aligned with architectural characteristics. For this reason, several researches on acoustic simulation of rooms were undertaken [6-10].

1.1 São Paulo Pinacoteca

The São Paulo Pinacoteca is the oldest art museum in the city, founded in 1905. It contemplates Brazilian art from the 19th century to the present day. It is installed in the former Lyceum of Arts and Crafts, designed at the end of the 19th century originally by the architect Ramos de Azevedo. In the 1990s it underwent an extensive renovation with an intervention project, led by architect Paulo Mendes da Rocha, along with architects Eduardo Colonelli and Welliton Torres. Paulo Mendes da Rocha is an exponent of Brazilian architecture, winning the Pritzker Prize, the most important of the world architecture, in the year 2006. [11]

The importance of installing the Pinacoteca in the old building of the Lyceum of Arts and Crafts goes beyond the requalification of the use of a building that was in decadence. The region in which the museum is located is emblematic in the city, because while it is an important tourist spot, it is also one of the places that suffer the depreciation of the central region, very common in large metropolises. The revitalization project for the installation of the Pinacoteca presents an important meaning for the architectural intervention in preexistence. According to Müller (2000), in the case of the Pinacoteca, the dialectical tension between the architectural legacy of the past and the present architecture results in the immanence and inexorability contained in the museum idea, where the human expressions of various circumstances - temporal or localities - converge, juxtapose themselves together and form the whole. Thus the Pinacoteca, until then one more among the artistic museums of the capital of São Paulo, presents itself with a museological value emphasized to the being affected by the timelessness of the essential action of the Architecture. [12]

The complete building has 10.815,0 m² of area, distributed in three floors, where the programs are different. The ground floor is where all the administrative organization is found, besides auditorium. The first floor houses short-term exhibitions, so that the layout undergoes several transformations as exhibitions change. The second floor is intended for permanent or long-term exhibitions, which may remain for a few years. The analyzes of this work are concentrated in galleries of the second floor, justified by the long permanence of the layout of the rooms, which allows a more judicious work for future comparisons. Figure 1 shows two external images of the Pinacoteca, located in *Square of Light*, one of the most striking places in the city of São Paulo, where the Light Station is also located.

Figure 1 – Pinacoteca of São Paulo. External view.

Source: http://pinacoteca.org.br/

Figure 2 shows the floor plan of the second floor. The upper band is the area where the rooms are studied in this work. These are the galleries 13, 14, 15, 16 and 17. It is observed that they are interconnected by a central aperture. Table 1 shows the area and volume of each gallery.

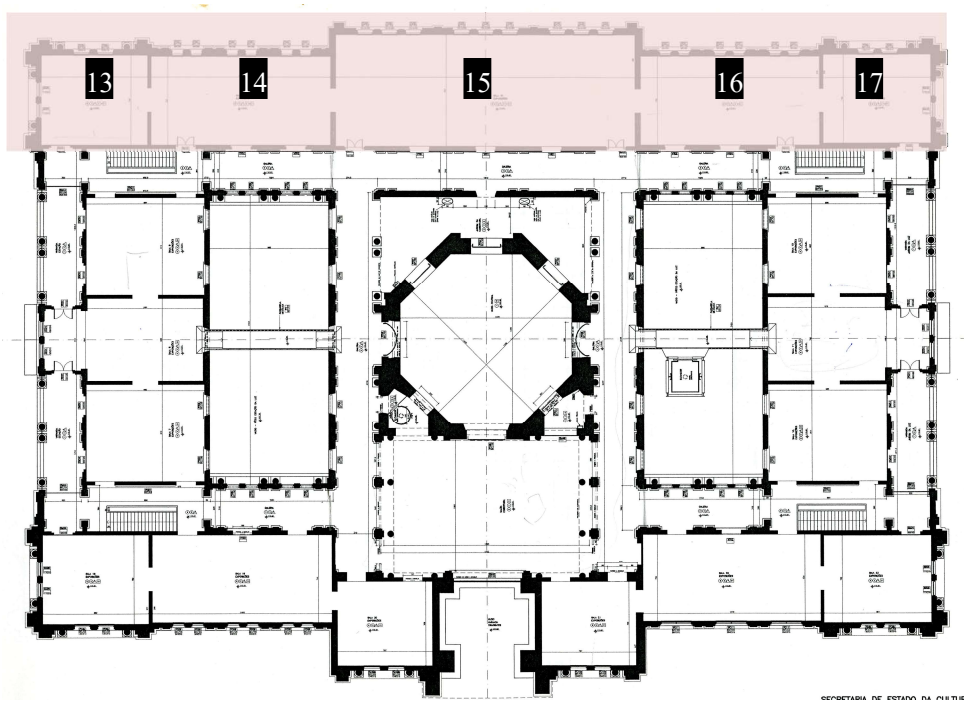

Figure 2 – Second floor. General Plan.

Source: Cedoc Collection/ São Paulo Pinacoteca

Table 1 – Areas and Volumes of the galleries

Sala	Area (m^2)	Volume ($m^{3)}$
Gallery 13	65,8	440,9
Gallery 14	110,2	738,3
Gallery 15	230,8	1546,4
Gallery 16	109,9	736,33
Gallery 17	65,9	441,5

The exhibition model is the traditional European, linear, with the layout of the works on the walls surrounding the room. Figure 3 shows an internal image of one of the rooms.

Figure 3 – Hall Exhibition

Source: https://pinacoteca.org.br/programacao/arte-no-brasil/

2. MATERIALS AND METHODS

2.1 Model and Simulation

For this work, galleries 13, 14, 15, 16 and 17 were selected, which are interconnected. In order to meet the objectives of this work, the acquisition of the results began with the three-dimensional modeling of the room. Commercial software was used to model the museum.

With the three-dimensional model finalized, simulations of the acoustic conditions of the room in the Odeon (version 11.23Combined) software were started.

The simulations were performed with the source allocated in each of the rooms where the microphone responses were captured in all other rooms, which are interconnected. The configuration in each room was of two source positions and three microphone positions, with the exception of gallery 15, with four microphone positions. Figure 4 shows the positions of the source (P1 to P10) and signal reception microphone (1 to 16).

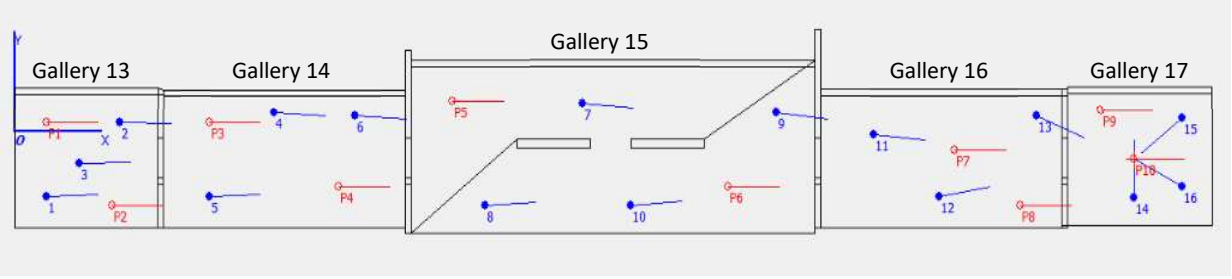

Figure 4 – Second floor, galleries 13, 14, 15, 16 and 17. Source and microphone positions for simulation.

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3. RESULTS AND DISCUSSION

For the purposes of analysis, each acoustic parameter is presented with five graphs, so that each presents the position of the source and the columns are the average results per frequency, in each room for that source. Each column also displays the standard deviation bar at each frequency.

3.1 Early Decay Time (EDT)

The results of EDT are presented in the graphs of Figure 5. It is possible to observe that the value of EDT is always smaller in the microphones that are in the same room of the source. This is a natural trend, since the first 10 dB of SPL decay is analyzed. The average results of each room are proportional, related to the distance of the receiving microphone from the source signal. In the rooms where the source is, a curve in parabola is observed, with higher results in the central frequencies, around 3,2 to

3,4 seconds for 500 and 1 kHz respectively.

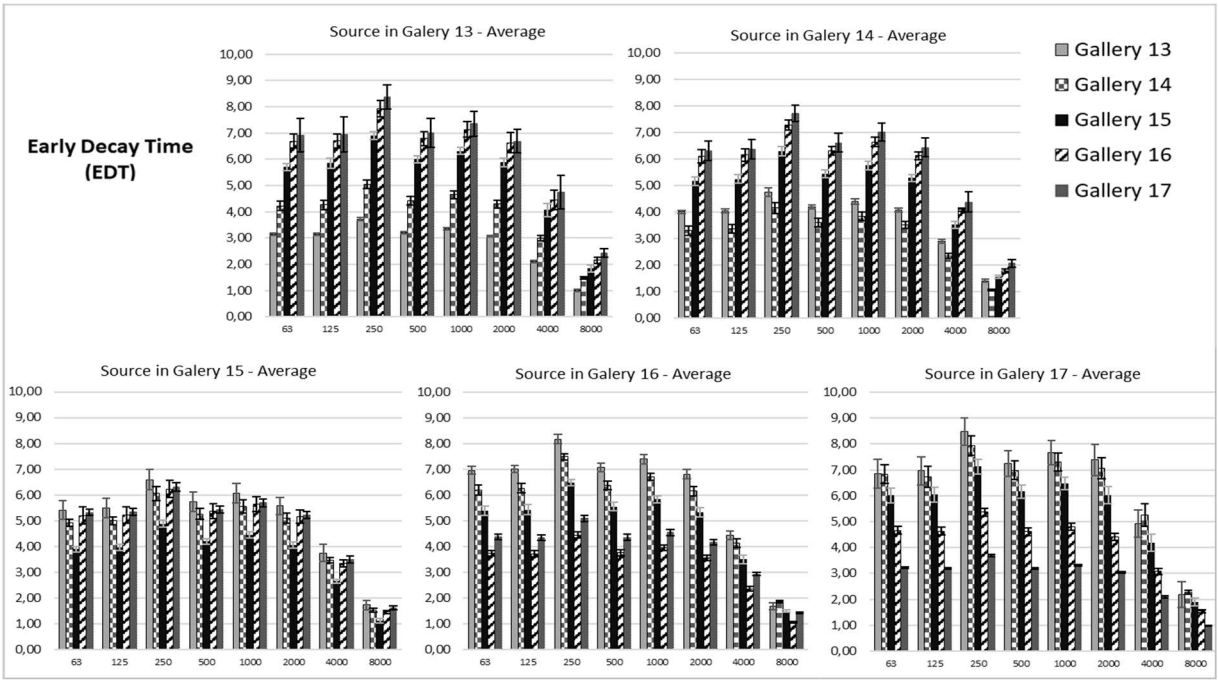

Figure 5 – Results of EDT. Each graph shows the average results for each position of the source.

3.2 Reverberation Time (T15)

The results of RT are contained in the graphs of Figure 6 . It is observed a similarity in the graphs profile between RT and EDT, so that the average of results in the room in which the source is allocated is always smaller. As the source-receiver distance increases, the values increase as the microphone is exposed to the reverberant field. Curves in parabola format are observed, with the highest values concentrated between 500 and 2 kHz, around 3,5 s to 3,8 s in the rooms where the source is positioned.

The Brazilian legislation does not present an ideal RT for museums, because it is not a room of the critical audience. In a case study [4] at the Serralves museum, in the city of Porto (Portugal), with modernist architecture, designed by the architect Álvaro Siza, it was reported the difficulty of finding bibliography with RT indicators ideal for museums. In this research mean values of RT (500, 1 kHz, 2 kHz), between 1,0 and 1,4 seconds were used as a guideline. These values were chosen according to a survey carried out during the study but there is no standardization. However, the values used in this work may serve as a valid reference.

It is observed that the values are considerably above the indices taken as reference for this work, which is between 1,0 and 1,4 seconds in the frequencies of 500 Hz, 1 kHz and 2 kHz. On the other hand, this study did not reach the experimental phase yet, and model adjustment may be necessary. Only the experimental part will determine if these parameters are higher than the recommendations.

It is observed that the results follow the same sequence of EDT, but in the case of the RT it is possible to verify a greater proximity of the results. The closer results for RT are explained by the fact that RT is found from the decay between -5 dB and -25 dB. On the other hand, the EDT is obtained from decays between 0 dB and -10 dB. The initial decays tend to be more irregular than late decays. For this reason, the EDT values tend to be more irregular than the RT values.

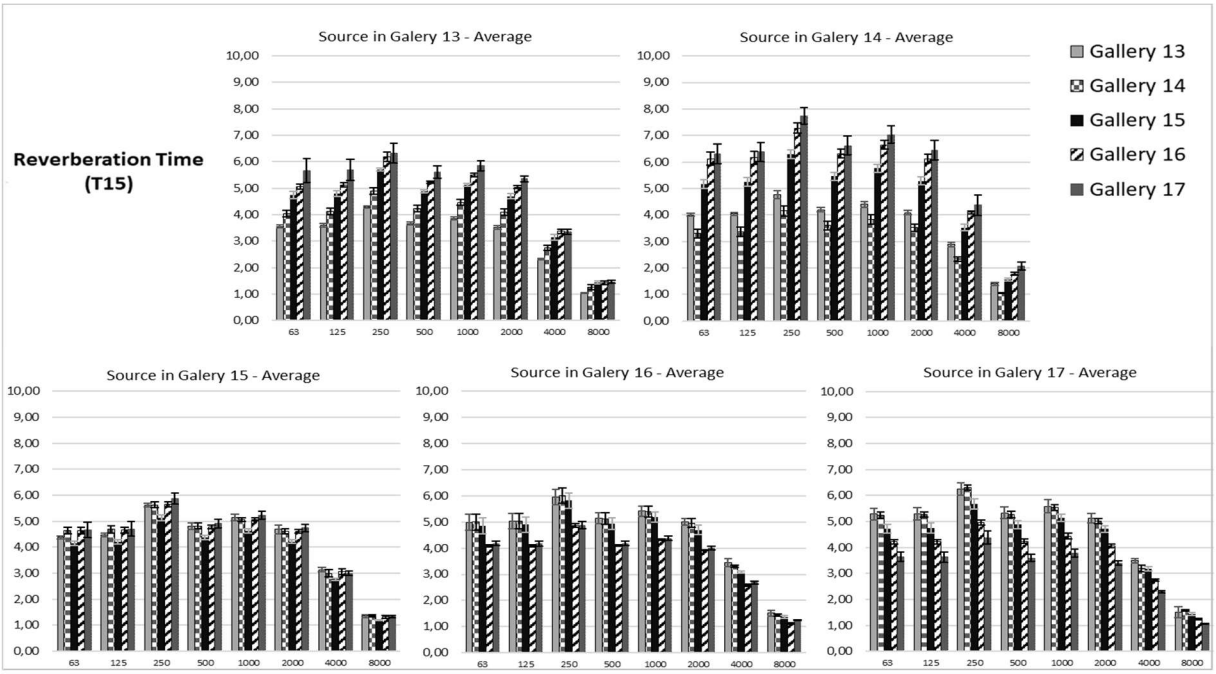

Figure 6 – Results of RT. Each graph shows the average results for each position of the source.

3.3 Definition (D50)

The results of D50 are shown in the graphs of Figure 7. It is observed that in situations where the microphone and the source are in the same room, D50 is better in this room than in other rooms, above 0,25 in the frequencies of 500 Hz, 1 kHz and 2 kHz. The receivers closer to the source are more exposed to the direct sound and stronger first reflections. This feature will make the D50 increase much more than for the most distant points.

This result is below the values indicated in standard 3382-3: 2009 [1], which considers acceptable values between 0,3 and 0,7 for an intelligibility to be satisfactory.

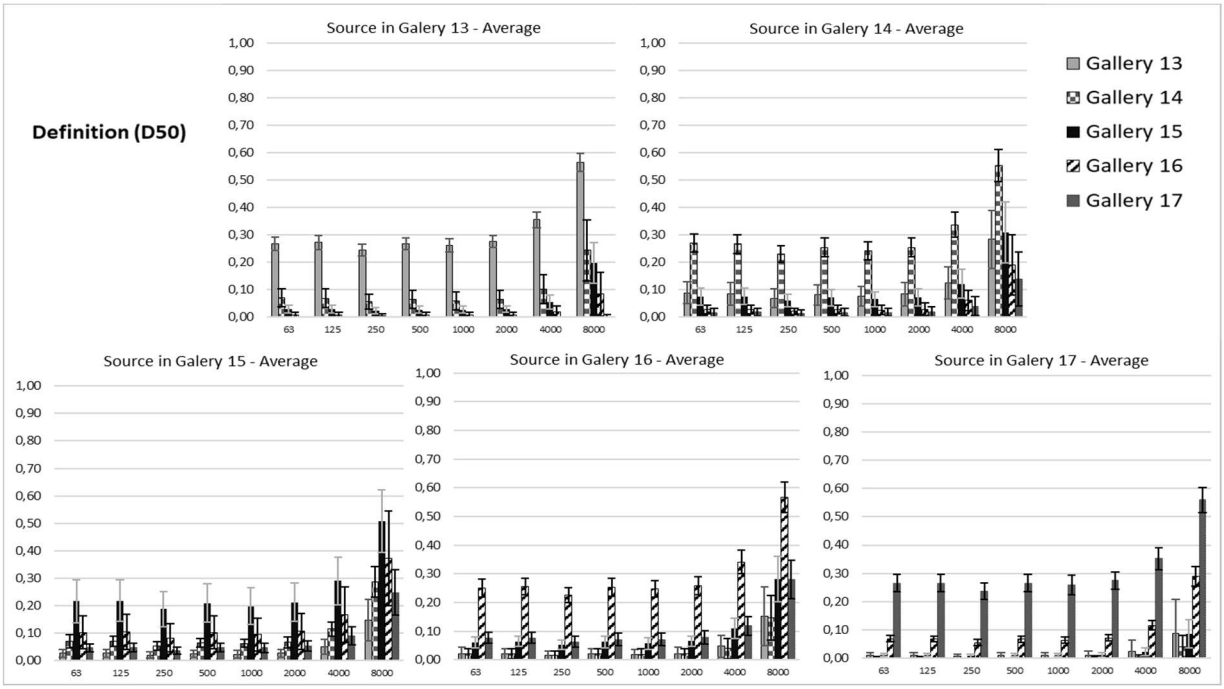

Figure 7 – Results of D50. Each graph shows the average results for each position of the source.

4. CONSLUSIONS

This work approached the acoustic simulation in a three - dimensional model of a museum with neoclassical architecture. The results of Early Decay Time (EDT) and Reverberation Time (RT) were very similar, with smaller results in rooms where microphone and source are allocated in the same room. The mean of the results between 500 Hz and 2 kHz for EDT was 3,2 to 3,4 seconds and for the TR it was 3,5 to 3,8 seconds. Both have rooms that are extremely reverberant and with results much higher than the 1,4 seconds recommended by Gonçalves, 2012 [4]. Museums are environments with little presence of absorbent materials. The Pinacoteca presents extremely reflective coating materials, besides the rectangular shaped rooms, interconnected to each other, this favors the reverberation sensation.

In the experimental phase, these results must be revisited and the model adjusted accordingly. On the other hand, it is a fact that the architectural characteristics of the place, composed of form and e coating that contribute to these high values.

The results of D50 show a room with extremely low Definition factor, hardly exceeding 0,3 (30%) of D50. Naturally, the results of the microphones closest to the fonts are superior to the more distant microphones.

The Definition of the permanent exhibition hall is low, however, it should be noted that museums are places of short-range dialogues. On the other hand, it is important that there is at least an average room definition so that audible warnings, especially in case of emergencies, are perfectly understood. This is a security issue.

Finally, it can be affirmed that the simulations provided coherent answers to the situation of the building, made of highly reflective materials and expressive volume, with rooms interconnected.
It is possible to understand that the building may present some acoustic problems due to the high RT, which may impair speech intelligibility, privacy and comfort in general. Museums are not places for critical audience, so conversations occur with people close to each other, but it is important to note that better D50 results are important especially when audible warnings happen to the public.

This work is part of a doctoral research that is under development. These were the first results about the simulations of this museum. Other studies are in continuation for detailed investigations of the problematic that involves museum acoustics and experiments will be carried out in the near future.

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