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Analysis of the Acoustic characteristics of a Museum of Modernist Architecture - Art Museum of São Paulo Assis Chateaubriand

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ABSTRACT

The architectural design involves the knowledge of variables of fundamental importance to a quality result. Acoustically characterizing museums delivers design directives of these buildings according to the precepts of acoustic comfort of the users. The museums have an important educational role, therefore valuing these buildings goes beyond the principles of museology, such as the rules for conservation of works. This work deals with the acoustic characteristics analysis of the Assis Chateaubriand São Paulo Art Museum, located in São Paulo city, Brazil, being the most important collection of European art in the Southern Hemisphere. The architectural design of modernist style is authored by architect Lina Bo Bardi becoming a landmark of 20th century architecture. The exhibition mode of the works, which instead of the traditional linear exhibition through the installation of the works on the walls uses crystal easels in the middle of the gallery is also a feature that tells how avant-garde the design of this museum. The acoustic studies were performed through simulation of the three-dimensional model in computational software with comparisons between source position and microphones and also the way of exposition of the collection. This work is part of a PhD research that is underway.

Keywords: Room Acoustics, Simulation, Museum

1.0 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 São Paulo Art Museum, which has modernist architecture and is an icon of this movement in Brazil. 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), Clarity (C80) 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 Clarity (C80) parameter analyzes the intelligibility of the articulations of the musical notes. It is determined by the energy ratio of the impulsive response that reaches the listener in the first 80 ms and from the 80 ms to its end (in decibel scale). In this way, clarity is a subjective term that describes what the details of a musical performance are perceived in relation to the masking of details by the reverberant sound [1]. Although museums are not exactly places for musical performance, this activity can happen in museums. 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 C80 and D50 parameters have typical values indicated at the standard ISO 3382:2009 [2], related to the average

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between 500 and 1000 Hz. For Clarity (C80), this value lies between -5 and +5 dB. For the Definition (D50), the standard consider acceptable if it lies from 30% to 70% [2]. It is known that this is a percentage value and, the closer to 100%, the better speech intelligibility condition.

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 [3]. Jónsdóttir [4] 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 museums. The need for privacy of speech was also pointed out in studies carried out in the Serralves Museum, Portugal [3,4], 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 [7].

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 [7-11].

1.1 MASP – São Paulo Art Museum

The São Paulo Art Museum is the first museum of modernist architecture in Brazil. Its foundation was in 1947, where it occupied a building in the center of the city for twenty years. The famous building that marked the history of Brazilian architecture, which is being studied in this work, was inaugurated in 1968, becoming the definitive headquarters of MASP. The building has 11.000 square meters divided into 5 floors. Its volumetry is a suspended by a porch that sustains 74 meters of span, where at the time was established as the largest span in the world. It is an icon in the city of São Paulo. In 1982 it was registered by CONDEPHAAT - Defense Council for the Historical, Archaeological, Artistic and Tourist Patrimony of the State and in 2003 by IPHAN - Institute of National Historical and Artistic Patrimony. Figure 1 shows an external image of MASP.

Figure 1. MASP. External view from Paulista Avenue.
Source: http://museubrasil.org/es/museu/masp-museu-de-arte-de-sao-paulo
Acces in 27-03-2019.

This work approaches a permanent exhibition hall. It is a hall of 2.100 m² and a volume of 12.600 m³. The materiality of its interior is composed of concrete floor, whole glass envelope and slab in apparent concrete. Lina Bo Bardi combines in her architecture the rough and unfinished surfaces with lightness, transparency and suspension [12]. The great difference of this museum is in its form of exhibition of the paintings. One of the most outstanding features of MASP is the exhibition model, where the paintings are displayed on crystal easels (glass supports to expose paintings). The museum is the only one in the world that adopts this radical system of exposing paintings, which were also designed by the architect Lina Bo Bardi, integrated with the architectural design of the museum on Paulista Avenue. One of the proposals were that the works were suspended in the air, where the theme is carried by a kind of forest of pictures. There is an approach of the public with works, becoming more accessible, since there is no sequence of visualization of the works of art established, each visitor defines his own course within the museum, of free form, between the easels. The finishing materials are basically composed of concrete and glass. Figure 2 shows images of the interior of the permanent exhibition room and glass easels with two points of view.

Figure 2. MASP. Permanent exihibition hall with crystal easels with two point of view.
Source: http://museubrasil.org/es/museu/masp-museu-de-arte-de-sao-paulo
Acces in 27-03-2019.

2.0 MATERIALS AND METHODS

2.1 Model and Simulation

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 two configurations of the museum. The first one, with the crystal easels according to the expository model of the place. Afterwards, studies were carried out in the hall without glass easels. Thus, it was possible to evaluate if there is interference in the acoustic conditions by the configuration of the expository model.

From each finalized 3D model, the simulation was started in the Odeon (version 11.23Combined) software, with the following data:

- Omnidirecional sound sources;
- Two source positions, in the region of the main entrance of the hall;
- Nine microphone positions for signal reception.

In both case scenarios, the microphones positioned at the same places, so that a comparison was possible. Figure shows an image of the simulation with and without the easels. The first image shows the two points of source (P1 and P2 in the image were “point of source”). The blue points are the receiver microphone points. The second imagem shows only P1 because P2 is in off for the simulation, but the position is equal the first image.

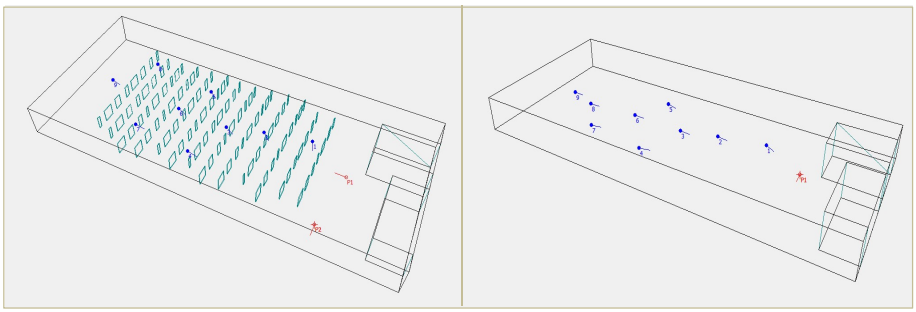

Figure 3. Three-dimensional simulation with and without the easels

3.0 RESULTS AND DISCUSSION

The analyzes were performed from comparisons between source-receiver pairs and scenario configuration (with and without easels). For each acoustical parameter there are three graphs. The first graph is valid for the configuration without the easels and shows the results for the nearest receiver microphone (RM1) and the farthest receiver microphone (RM9) for each of the sound sources. The secong graph is the same as the first, but for the scenario with the easels. The third graph shows the average results of the receivers ensemble for each point sound source (P1 and P2) with the two room exposure settings. The analyses from the farthest point to the nearest point of the source is justified to check how much of the criteria is lost when moving away from the source. In addition, it is also valid for the study of the influence of the easels in relation to the distance of the listener to the source.

3.1 -Early Decay Time (EDT)

The results of EDT are presented in the graphs of Figure . It is observed that at 63 Hz is where the greatest results are presented, so that it is with the room without the easels that occur the largest, reaching EDT around 7,5 seconds. Up to 1 kHz, there is a decrease of the EDT values in the room without the easels. A secondary peak is found at 2 kHz band. When analyzing the result of the room with the easels, it is possible to detect nearer values between 125 Hz and 1 kHz frequency bands. The secondary peak is also found in 2 kHz, but with a smaller value. The room without the glass easels presents a harmonious relationship of results both in the microphone closest to the source and in the farthest. This can be related to the diffraction of sound waves promoted by the easels, which tend to make the sound field in the room more diffuse in that scenario. The diffraction is taken into account, at least, in part by Odeon. When the room is studied with the crystal supports, the most distant point of the S2 source is that it presents the greatest results.

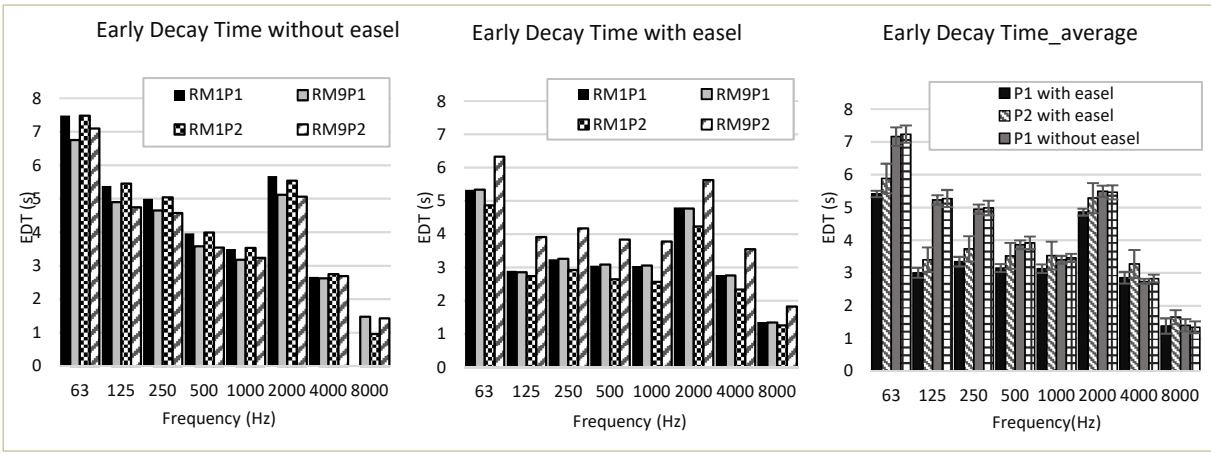

Figure 4. Results of EDT. The first graphic is the exhibition hall without easel with two source configurations. The second graphic is the exhibition hall with easel and with two source configurations. The thirt graphic is the medium results with both sources and room settings.

It is possible to observe that the configuration without the glass easels inside the enclosure is that it presents the highest results up to the frequency of 2 kHz. For higher frequencies the EDT values are more similar.

3.2 –Reverberation Time (RT)

The results of RT are contained in the graphs of Figure 5. It is possible to observe behavior similar to the EDT, in which the 63 Hz Hz has the highest peaks, around 6,8 seconds. 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 [5] 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.

Higher RT values are found in the configuration of the room without the easels. In the frequency of 500 Hz, slightly higher values were observed without the easels, around 3,9 seconds, while with the supports these values were around 3,1 seconds. At 1 kHz the values are very close, around 3,4 s without easels and 3,2 s with them. This greater proximity of values is also observed in 2 kHz, where RT is observed between 4,8 and 5 seconds with and without easels, respectively. The distance ratio of the microphone to the source is repeated as observed in the EDT responses, 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.

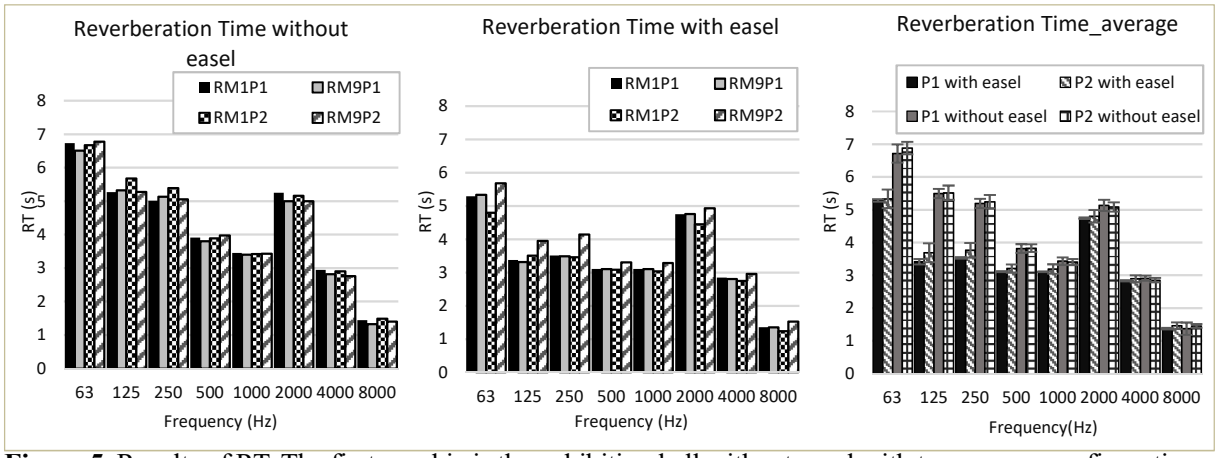

Figure 5. Results of RT. The first graphic is the exhibition hall without easel with two source configurations. The second graphic is the exhibition hall with easel and with two source configurations. The thirt graphic is the medium results with both sources and room settings.

When analyzing the averages, again the high similarity of the behavior of the curves with EDT is observed, with the highest values presented in the situation of the room without the glass easels. The frequencies of 500 Hz and 1 kHz present close values and both room and source settings, between 3,5 and 3,9 seconds. There is also the peak at 2 kHz, around 5 seconds and decreasing again at 4 and 8 kHz.

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.

3.2 –Definition (D50)

The results of D50 are shown in the graphs of Figure 6. It is observed that in the situation of the room without the easels the results of D50 are larger for the closest microphones, not reaching 0,4 of

Definition (40%) up to the frequency of 4 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. In the situation of the room with the easels, the results do not diverge so much in relation to the position of the microphone, observing similar results in both the closest and the most distant points, except for RM9 with P2. This can be again attributed to the diffraction of sound by the easels, which tend to even out the sound in the room. In this configuration, the D50 does not reach 0,3 (30%) between the frequencies of 250 Hz and 4 kHz. The mean results shows that the D50 only exceeding 0,3 at the 8 kHz frequency and high standard deviation, which is natural due to the characteristic of this parameter.

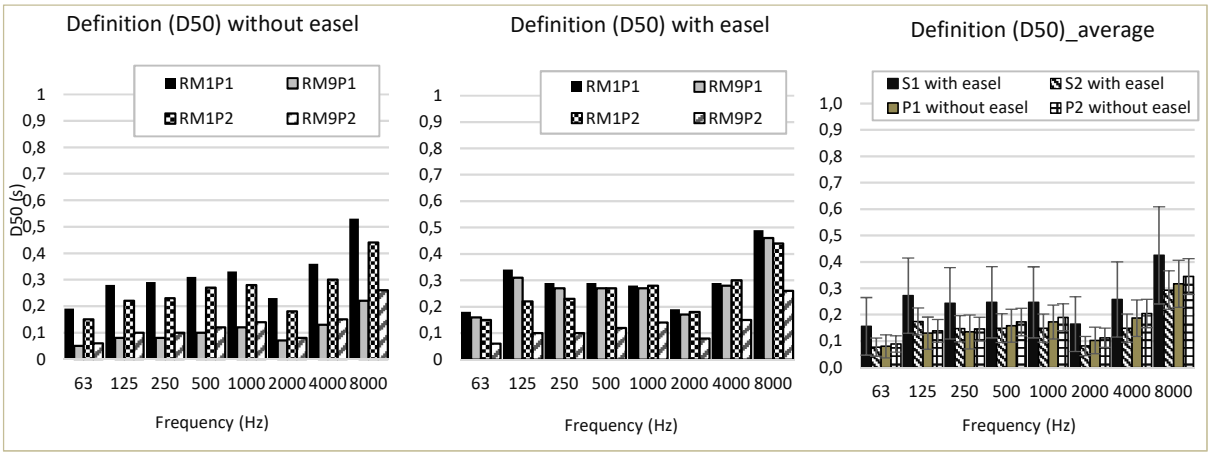

Figure 6. Results of D50. The first graphic is the exhibition hall without easel with two source configurations. The second graphic is the exhibition hall with easel and with two source configurations. The thirt graphic is the medium results with both sources and room settings.

3.4 –Clarity (C80)

The results of C80 are shown in the graphs of Figure . It is noted that with the exception of 8 kHz, all results are negative, with averages ranging from -2,5 dB to -8 dB across all frequency bands. The negative results means that there is less energy in the direct sound and first reflections than in the reverberant tail. Like the D50, the C80 is influenced by the source-receiver relationship. The microphones farthest from the source have the greatest negative results in both positions. When analyzing the results of the hall with the glass easels, there is a greater similarity of responses between RM1P1, RM9P1 and RM1P2, so that RM9P2 presents a trigger of negatives values for C80.

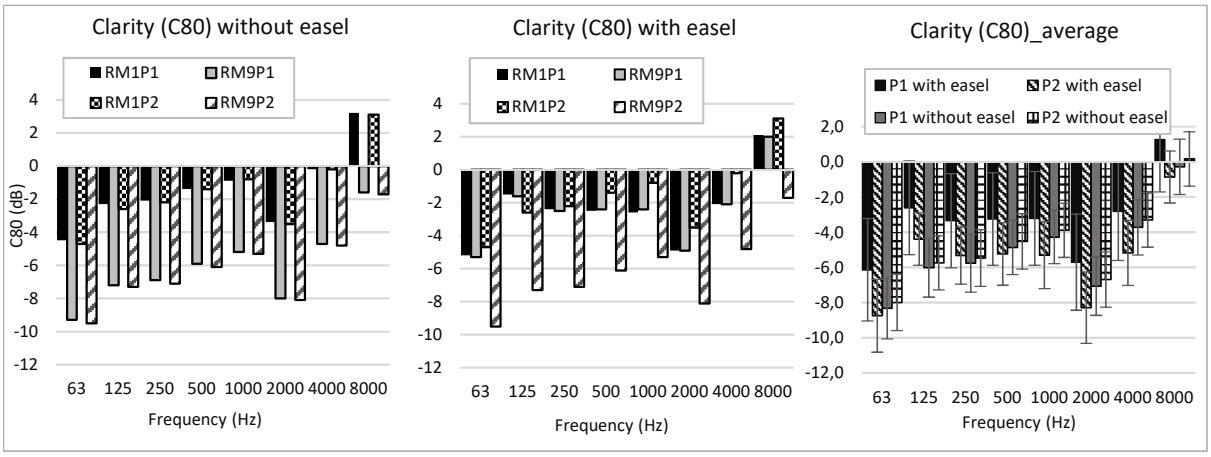

Figure 7. Results of C80. The first graphic is the exhibition hall without easel with two source configurations. The second graphic is the exhibition hall with easel and with two source configurations. The third graphic is the medium results with both sources and room settings.

The average responses of C80 show predominantly negative results, considering that the room is highly reverberant this is a result consistent with the other parameters.

3.0 CONCLUSIONS

This work approached the acoustic simulation in a three - dimensional model of a museum with modernist architecture.

The results of Early Decay Time (EDT) and Reverberation Time (RT) were very similar, showing that the room is highly reverberant. In both parameters, the simulations of the room with the glass easels showed slightly lower values, indicating that the configuration with these elements allows a small reduction in the results. RT ranged from 3,2 to 5,5 seconds at the frequencies of 500, 1 kHz and 2 kHz, well above values between 1,0 and 1,4 seconds for this frequency range [5]. 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 concrete and glass, besides the large volume and the geometric shape 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. In the situation of the room with the easels, it is observed that the farthest microphone (RM9) with the source in the corner of the room (P2) is that it presented smaller D50 than the others. This point is exposed to the highly reverberant field, which justifies this result. 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.

The results of Clarity (C80) presented predominantly negative results, varying from -2,5 to -8 in all frequencies, except for the frequency of 8 kHz. These results are in agreement with the high RT found. It is not usual musical activities in this specific room of the MASP, therefore it is a parameter that influences less in the comfort of the regulars of the place.

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.

It is also possible to observe that the simulations do not present a great difference in the acoustic performance of the place with and without the glass easels. In addition, there is no other way of studying how MASP glass easels can influence acoustic behavior other than with simulations, since it is a permanent exhibit room, these elements do not leave the room. 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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