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Acoustics and architecture in office buildings: How the site plan and the shape of the building affect the levels of incident noise on façades

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Abstract

The lack of soundscape analysis in the early stages of the building construction process is a common practice in real estate developments in Brazil. Acoustical consulting begins after the location and the shape of the building has already been defined, limiting the possibilities of solutions that may reduce the acoustic demands for façades. With the increase in noise pollution in Brazilian urban areas, it is important to emphasize that the acoustic consulting should be initiated during the land prospecting phase in order to improve the possibilities of achieving a more effective acoustical performance of the building. This article aims to evaluate how noise mapping can be used as a tool for decision making about façade design and building location. Therefore, this paper presents a case study in which computer noise simulations were carried out considering the incident noise on a real building, with two alternative proposals for the architectural design which enable lower values of noise incident on the facades and costs reduction.

Keywords: office buildings, environmental noise simulation, architectural design, acoustic performance of glass façades.
Acoustics and architecture in office buildings: How the site plan and the shape of the building affect the levels of incident noise on façades.

1 Introduction

Loud or unwanted noise can become troublesome and generate a number of consequences for the occupants of corporative environments, such as stress, difficulty in concentrating, irritability, increase in heart rate and headaches, among other psychological and physiological injuries [1][2][3]. As an important consequence, relevant factors to be avoided in corporate environments such as productivity loss and interference with communication are observed.

According to the World Health Organization [3] the extent of noise-related problems is large. For example, in the European Union, 40% of the population is exposed to traffic noise with sound pressure levels exceeding 55 dB (A) during the day and 20% being exposed to levels exceeding 65 dB (A). The equivalent noise level of 65 dB (A) is regarded as the upper threshold for acoustic comfort, and continuous exposure to values above this limit may cause various pathologies aforementioned [2]. Commercial buildings located in urban contexts with hostile soundscapes can suffer from the influence of vehicular traffic such as cars, trucks, motorcycles, trains, subways, and airplanes.

In order to reduce urban sound levels, municipal and national legislations set noise limits for different activities in order to ensure a minimum comfort of the population. In the case of road traffic, the control of sound levels is related to the urban planning and factors such as land use, speed and arrangement of roads, bus stop locations and urban density. This noise emission control associated with the urban planning is still quite incipient in Brazil.

Due to the growing problem related to noise pollution, noise mapping is an important tool for data collection and assessment of environmental noise in communities. The maps generate average values from different sources, giving emphasis to road traffic and aircraft noise. [1]

Through the analysis of these maps, it is possible to evaluate how the building to be constructed will be affected by noise levels generated in the immediate environment of the building lot and thus base initial projective decisions as implementation and design. In addition, these tools can display trends in the increase of noise levels and aid in the urban planning for better determination of the land use. Elements such as shape, façade materials and building location can be optimized to minimize the effects of noise in the building, thus raising the level of comfort and possibly also reducing costs. [1]

The current process of real estate development in Brazil in general is characterized for the lack of local soundscape analysis in the early stages of design studies. This phase is characterized by an economic and legislative bias, neglecting that high noise levels in the immediate surroundings of the future construction may affect their performance and overload the demand for sound insulation on facades, increasing the total cost of the construction.
As a standard practice, the acoustic consulting activities are conducted after the approval of the legal project or in the preliminary study stage, steps in which the location, the siting and the shape of the building have already been defined, limiting design solutions that meet the acoustic demands.

The current architectural trend for corporate buildings increasingly aims for transparency, through the extensive use of glass, slender structural profiles and lightness of the appearance of the materials used. This leads to lightweight sealing, such as glass facades that need to be specified and implemented carefully to meet the acoustic insulation requirements.

With these reasons in mind, this study aims to evaluate the influence of noise mapping as a tool for decision making, analyzing the performance of class AAA corporate commercial buildings located in a region of intense traffic noise levels. For this, a case study is presented in which simulations of the noise in the facades of a real building were made and design alternatives aimed at achieving lower values of incident noise on the facades were proposed.

2 Background

The real estate development is composed of a 22-storey Class AAA corporate tower, with 18 floors being offices, a parking building, an outdoor parking area and a large covered access. The real estate development is located at Rio de Janeiro Avenue, in the port area of Rio de Janeiro. The site has 13,000 square meters with 51,756 square meters of constructed area totaling 32,321 square meters of leasable area.

The terrain is surrounded by routes with intense traffic, such as Rio de Janeiro Avenue, access road to the building. This is a two-way avenue with four-lanes in each way, on which stands the “Perimetral Viaduct”, which contains 5 lanes. These streets are characterized by intense flow of heavy vehicles, mainly buses. The point of passenger exit and boarding is located across from the building. Near the bus stop, just in front of the building there is a traffic light for cars and pedestrians.

The mains façade is located at a distance of only 3 meters from the Rio de Janeiro Avenue and 12 meters from the “Perimetral Viaduct”. This is a 10 meters high viaduct, coinciding with the third floor level. Due to heavy vehicle traffic on these routes, the building facades and entrances are hit by high noise levels. The real estate development occupies the area highlighted in blue as depicted in Figure 1.
3 Methodology

Noise measurements were carried out at the street level of the main building facade extension and also on the 3rd floor in order to calibrate the 3D model. The measurements were performed on 13/04/2015 from 12:30 p.m. to 13:30 p.m. Each noise measurement lasted five minutes. The methodology for the measurements followed the criteria established in NBR 10.151-2000: “Evaluation of noise in inhabited areas aiming the comfort of the community” – Procedure, Brazilian standard that determines procedures for noise evaluation in populated areas, to ensure the comfort of the community.

The acoustical evaluation of communities must rely on the development of noise mapping of the acoustical environment that includes real-time measurements, analysis of statistical levels and frequencies analysis. [4] Although there are regulatory standards regarding noise measurements, there is no acclaimed methodology to be followed for the simulation of environmental noise and acoustical mapping. [1]

The results of the measurements are presented in Graph 1. The values of $L_{Aeq}$ are expressed as a function of frequency for each measured point.
By means of noise measurements it was proved that the main values of contribution are in the low and medium frequencies. The main sound source found was the heavy vehicle traffic on Rio de Janeiro Avenue, with acceleration and braking of buses and trucks. The movement of cars and motorcycles was also a significant contribution.

3.1 Modeling

The methodology used was constituted by the case study of an existing building, for which the hypotheses were simulated in the software CADNA-A (Computer Aided Noise Abatement). The main function of the software’s is to calculate and estimate the environmental noise. The simulated conditions were as follows:

1) Scenario 1: current configuration;
2) Scenario 2: Increasing of the distance between the main façade and the Rio de Janeiro Avenue and the Perimetral Viaduct. In this scenario the building was located 16 meters farther from the road.
3) Scenario 3: Increasing of the distance between the main façade and the Rio de Janeiro Avenue and the Perimetral Viaduct. The building is 26 meters farther from the road and it was extended 10 meters in direction of the side parking lot. In this configuration the building position and shape have changed.
3.2 Environmental noise computer simulations

The methodology for the preparation of noise maps in built-up areas involves data collection, establishing criteria, calculation of sound levels on a grid system, arrangement of sound curves in 3D models. [5]. For the development of environmental noise simulations it is necessary to collect a variety of data to characterize the acoustical environment of the real estate development, such as the sound sources, the environmental characteristics, the type and the land use, the demographical information and the building characteristics.

The simulation results are presented through maps of equal loudness curves and tables of values obtained in the receivers. 3D models that plot the noise levels on the facades with their respective legend colors that relate different colors to different sound levels values can be created. The software input data to generate the models was as follows:

<table>
<thead>
<tr>
<th>CADNA-A Parameters</th>
<th>Model data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>International ou (User Defined)</td>
</tr>
<tr>
<td>Extrapolate Grid 'Under' Buildings.</td>
<td>Unable</td>
</tr>
<tr>
<td>Ground Absorption G</td>
<td>0.00</td>
</tr>
<tr>
<td>Temperature</td>
<td>23.8°C</td>
</tr>
<tr>
<td>Humidity</td>
<td>79.1%</td>
</tr>
</tbody>
</table>
3.3 Criteria

3.3.1 External Criteria

The municipal administrations have legislation relating to the noise criteria, however in many cases generate ambiguities and difficulties of implementation. Nationally, Resolution No. 001 of the National Environmental Council (CONAMA) of 9 March 1990, sets out noise emission criteria for comfort and health. This resolution is quoted that traffic noise levels (car, air or rail) must comply the standards established by the National Traffic Council (Contran). [7]

In the national standard NBR 10151: 2000 a 5 dB penalty is specified if the noise under investigation has impulsive characteristics or tonal components. The adjusted levels are comparable to the evaluation criteria-level (NCA). In the case of this study were not identified noises with these characteristics.

According to the Mayor of the city of Rio de Janeiro, the building is located in the area known as “Planning Area” at port region. This area is classified as “mixed area with commercial and administrative vocation,” and, according to NBR10.152: 1987, the permissible noise levels during the day and night are, respectively, 65 dB (A) and 55 dB (A) [8].

3.3.2 Internal Criteria

The internal criteria of acoustic comfort for office dependencies are established by the standard “ABNT NBR 10152: 1987 - Noise levels for acoustic comfort”. The background noise level is rated by NC curves - Noise Criteria. This standard sets the following noise levels for offices:

<table>
<thead>
<tr>
<th>Room type</th>
<th>dB (A)</th>
<th>NC value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting rooms</td>
<td>38-42</td>
<td>30-35</td>
</tr>
<tr>
<td>Management offices/ administration offices</td>
<td>38-47</td>
<td>35-40</td>
</tr>
</tbody>
</table>

Table 2: dB (A) values and Noise Criteria (NC) curves for office dependencies.

To achieve the acoustic limits, it is necessary that all the construction and equipment fulfill the specific requirements. Speed limits in air conditioning ducts, water supply conditions, electrical and plumbing equipment are some of the items that influence the acoustic comfort. To define the sound field characteristics must be observed both the spread of airborne noise and structural noise [10].
3.4 Results

The following images and tables contain the results from computer simulations and their sound levels on the facades that were estimated.

<table>
<thead>
<tr>
<th>Facade</th>
<th>Noise level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>83</td>
</tr>
<tr>
<td>02</td>
<td>79</td>
</tr>
<tr>
<td>03</td>
<td>66</td>
</tr>
<tr>
<td>04</td>
<td>76</td>
</tr>
</tbody>
</table>

Table 3: Estimated sound levels
Source: (authors, 2015)

<table>
<thead>
<tr>
<th>Facade</th>
<th>Noise level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>81</td>
</tr>
<tr>
<td>02</td>
<td>76</td>
</tr>
<tr>
<td>03</td>
<td>64</td>
</tr>
<tr>
<td>04</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 4: Estimated sound levels
Source: (authors, 2015)

<table>
<thead>
<tr>
<th>Facade</th>
<th>Noise level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>78</td>
</tr>
<tr>
<td>02</td>
<td>73</td>
</tr>
<tr>
<td>03</td>
<td>64</td>
</tr>
<tr>
<td>04</td>
<td>73</td>
</tr>
</tbody>
</table>

Table 5: Estimated sound levels
Source: (authors, 2015)
4 Conclusions

Scenario 01 showed high levels of noise in the façades of the towers, especially on façade 01, the closest to Av. Rio de Janeiro and the Viaduct. The sound levels reached 83 dB, a level 38 dB (A) above the requirement of the standard for indoor environments of commercial buildings.

In scenario 02, the highest noise levels reached 81 dB on the facade 01, 2 dB less than the original scenario. This reduction is at the threshold of a level difference perceived by the human ear and thus does not represent a significant gain.

However, the results of scenario 03 showed a maximum level of 78 dB on the facade 01, a reduction of 5 dB compared with the original scenario. This reduction is significant, and clearly exceeds the threshold of human perception for noise level differences.

In all cases it was possible to notice that the facade 01 is most affected by noise, especially at the height of lower floors. In addition, due to the diffraction effect and location, the façade 03 showed lower values.

An analysis of the results of the simulations it is possible to conclude that scenario 03 is the one with lowest noise levels on the building facades and this improvement was obtained with simple shape and location modifications, without excessive changes in size or architectural concept.

In this scenario there was significant improvement not only for the higher floors but also at the ground level, on which the main entrance and lobby are located. By offsetting the tower towards the rear of the plot it is possible to plan green areas in front of the building, with enough vegetation to form a visual barrier to avenue with high traffic flow. Also, this scenario allows the use of thinner glass, reducing costs.

For this study, the influence of traffic on Av. Rio de Janeiro and the Perimeter Viaduct was prioritized. The next steps for this research will be noise measurements on the surrounding roads in order to create a newer model for the calibration and simulations of other scenarios of building shape and also considering also include the neighboring empty lot.

Acknowledgments

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References


