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Double Skin Façade for university building in Mexico located in a high noise area

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Abstract:
The noise inside the building of recent construction (2014), to house the classrooms of the "Postgraduate Unit" of the UNAM, is located above what is accepted by the International Standard of Acoustic Comfort of 35 dBA. According to the data collected, it has been determined that noise enters the construction through the façade adjacent to Av. Insurgentes. This façade, due to the materials used in its construction - concrete, glass and aluminum - does not provide enough acoustic insulation, which is materialized in internal noise. At the same time, it must be considered that university legislation does not allow altering the original façades, thus ruling out this possibility as a solution to the problem. Therefore, a Double Skin Façade (DSF) was proposed, with no sides to close it. To simulate the NPS between the original façade and the DSF, a software was used and it was possible to know that the proposal is adequate. Furthermore, it could be proposed as sustainable architecture.

Keyword: Acoustic comfort, Noise, Sound Pressure Level

1. Introduction

At present, the interest in studying the effects of noise in cities has gained relevance, due to its harmful effects on people's lives. Urban development, industry, transport and, in general, modern life in cities are the cause of high noise pollution. These activities, among others, alter the natural balance and generate undesirable sounds that affect and harm the inhabitants of large cities.

2. Problem statement

The explosive growth of the world population has caused a huge demand for architectural spaces of all kinds. These architectural designs require special proposals and solutions in their construction and operation. Other factors to consider when addressing the noise problem are: ventilation, heating, lighting, orientation and location, among others. An important element in this sense are the construction materials that often do not provide well-being or acoustic comfort, which is now known as sustainability [1]. This concept, often encompassed as user convenience, requires a better and more careful explanation. In this sense, comfort is to eliminate any unpleasant sensation that prevents concentration, it must offer protection against the negative consequences of an explosive population growth such as overcrowding and exposure to pollutants (**noise**, toxic gases, radiation, etc.).

2.1 Noise as a pollutant

In recent decades, noise in urban and suburban areas around the world has increased to become a pollutant considered a public health problem. As a result, its effects on people whose lives are altered in physiological, psychological, economic and social aspects (PiPEyS) are increased.

2.2 Noise

It can be defined as the unpleasant part of the sound [2]

3. Noise levels and their relationship with learning

According to the WHO, the degree of affectation of PiPEyS varies according to the NPS, the proximity to the source and the time of exposure affect several cognitive processes: more than 40 dBA make calculation activities difficult; at 50 dBA, cognitive efficiency drops; at 55 dBA, memory impairment; after 60 dBA, the difficulty of capturing auditory information appears; at 64 dBA, slow learning occurs and at 70 dBA, reading comprehension problems appear [3].

In the UP-UNAM a survey was carried out [4] among users where the following results were obtained: 48.4% declared that environmental noise within this architectural complex is a problem. 59.3% think that, mainly, traffic noise affects the academic activities carried out in the classroom. On the other hand, 64.8% consider that Building “B” is the one that presents the most problems compared to the rest of the buildings. 42.2% stated that what causes discomfort to users is vehicular traffic and, finally, 56.1% said that the main source of noise is Av. Insurgentes

3.1 Professors and noise

When teachers change the level of voice intensity to compete against RF, they increase the signal-to-noise ratio (RSR) [5], thus increasing the risk of voice disorders [6,7], which is in fact a common condition among students. teachers [8]. In addition, students are affected in their learning process. This confirms the fact that, in the last two decades, environmental factors have a more detrimental effect on voice disorders than genetic factors [9, 10].

A recent study found that, in a class, the teacher speaks almost 46% of the time [11], so he actively seeks to incorporate students, recognizing them as interlocutors.

4. Geographic delimitation of the study

UNAM has the title of being the University of the Nation, the CU campus is located south of Mexico City (CdMx), with a total area of 733 hectares. It is located in the 100th place of the best universities in the world for its quality worldwide, and is considered the 2nd in Latin America. It is estimated that in the 2021 academic year there are 42,000 teachers, 350,000 students, as well as workers who require mobility within the campus, so there is a substantial increase in vehicle traffic and, consequently, a high generation of noise.

The buildings of the National Autonomous University of Mexico (UNAM), especially in Schools and Colleges, have shown their limitations to coexist with a constantly growing megalopolis. Its architectural concept has not changed in the last 70 years and the new buildings have been designed and constructed in practically the same way as when the campus of the University City (CU) was created in 1952 (Figure 1). It is worth mentioning that, at that time, the area where the UC was located was considered a rural area, without noise and without services. In those years, vehicular traffic was very low, so noise was not considered a form of pollution. Currently, UC has several vehicular access routes and many campus buildings are located next to or very close to internal and external communication routes.

A study of AC qualifiers is presented in 10 classrooms identified with noise pollution problems, within the Postgraduate Unit (UP) of the UNAM. The architectural complex is of recent construction (2014). It is located next to Av. Insurgentes, -one of the most important in CdMx- where thousands of cars and cargo vehicles circulate daily. One more element is that the set of buildings is located between the campus streets, so local traffic also interferes with the acoustic environment Figure 2.

4.1 Limitation of space to investigate

From the set of buildings that make up the UP-UNAM, building "B" was chosen because of its location in front of Av. Insurgentes. Second and third level classrooms were studied for being the most exposed to noise. The first floor, ground floor and basement spaces are not occupied, since, as a result of their exposure to noise, they have been gradually abandoned. The study was carried out in the 10 classrooms during the days and hours of greatest vehicular traffic. They were chosen so that they represent the four types of classrooms in building "B", which are classified according to their volume as follows: 1) Cubicle ~ 19 m3; 2) Small classroom ~ 53 m3; 3) Medium classroom ~ 107 m3; 4) Large classroom ~ 205 m3. All the classrooms studied have a volume of less than 283 m3. The capacity of students within the classrooms is from 10 to 40 in each one.

4.2 Research method

For this case, the method to objectively evaluate CA required the preparation of data tables designed for this purpose. They were built taking as reference the qualifiers indicated in the standards: ISO 717-1 [12]; ISO 3382-1 [13]; ISO 16283-3 [14]; IEC 60268-16 [15]; ANSI / ASA S12.60-2010 [16].

Data collection was carried out in unoccupied classrooms with furniture, since permits were not obtained to do so with students and teachers.

The qualifier measurements were performed with the following equipment B&K brand: Sound level meter type 2270; omnidirectional source type 4292-L, amplifier type 2734; type 4189 microphones and Dirac software, under two general conditions:

1. Door and windows closed. To have a database line.
2. Open doors and windows, because the classrooms are passively ventilated.

The values are in octave bands of 125, 250, 500, 1 000, 2 000 and 4, 000 Hz, with measurement in" Fast" during the measurement, the height of the microphones was 1.20 m, as if the students were seated.

It is very important to mention that the ventilation through open windows is insufficient, so the access door remains open (cross ventilation).

5. Focus of this paper

The focus is experimental and the emphasis is on:

- Asses the proposals for architectural solutions.
- Evaluate the results with the Lima Predictor software [17].

6. International benchmarks

The specialized literature, related to AC within the classroom, has focused mainly on the level of Reverberation Time (RT) and Background Noise (BN). In the reference [18]. The values used as reference in this work are those of Table 1 of ANSI / ASA [7]. Reference values from other countries are also seen.

Figure 1 - University City under construction 1952

Standard /Country	RT min Seg	RT max Seg	Back-ground noise	Volume m³
ANSI ASA12.60-2010 Part - 1 (USA)	**0.6** 0.7 500, 1 000 2,000 Hz	**0.6** 0.7	**35 dB(A)**	**<283** >283
Holland		0.8		
France	0.4	0.8		<250
Germany	0.8	1.0		~250
Sweden	0.5	0.6		
Portugal	0.6	0.8		
Japan		0.6		~200
Finland	0.6	0.8		
United Kingdom	0.6	0.8		

Table 1 - International benchmarks

In order to bring clarity to the study, another qualifier to be used was addressed.

- Acoustic insulation, façade, Standardized Level Difference ($D_{2m,nT,w}$).

7. Outside measurement

The recorded LA_{eqs} were measured *In Situ*. Figure 2 and 3 shows how the SPL were obtained abroad in conditions a) and b) of each classroom.

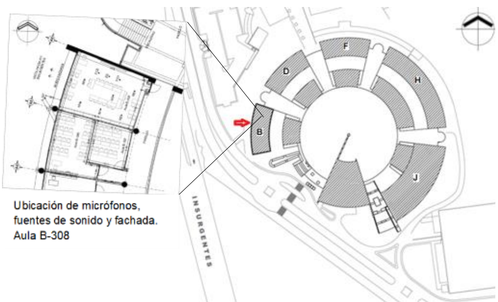

Figure 2- Location of the PU-UNAM. The arrow points to the building "B" where the classrooms are located.

Figure 3 – Position of the microphone to measure the SPL of vehicular noise outside the classroom at 2 min front of the façade.

8. Values obtained

The qualifiers were measured in natural listening conditions, real classrooms, with real ambient noises (vehicles of all kinds).

The figure 4 shows the RT values, measured in the 10 classrooms in building "B".

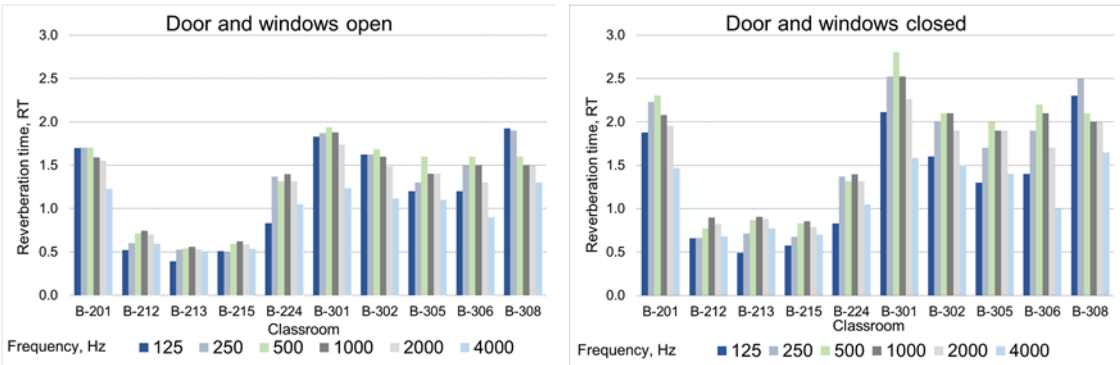

Figure 4 – RT measured within the classroom

The façade of each classroom in the only physical barrier that separates and isolates it from the outside noise that comes from Av. Insurgentes, Figure 5 and Table 2 shows its general acoustic insulation, that is, the Standardized Level Difference ($D_{2m,nT,w}$).

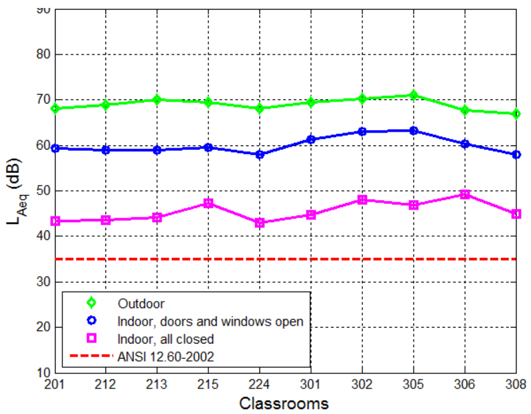

Figure 5 - SPL exterior - interior, ANSI / ASA

Classroom	$D_{tr,2m,nT,w}$	C	C_{tr}
B-201	32	31	29
B-212	28	28	25
B-213	27	27	25
B-215	24	24	21
B-224	24	23	23
B-301	32	32	30
B-302	23	23	22
B-305	29	28	26
B-306	30	29	29
B-308	31	30	29

Table 2 - Standardized level difference and adaptation term of spectrum C and C_{tr} [13].

9. Discussion of the results

Based on the qualifiers obtained, we know that:

- The AC in classrooms is adversely affected, disrupting speech intelligibility.
- The BN is very high, because the façade has a low acoustic insulation.
- The RT are very long due to the finishing material of the walls, as well as the furniture.
- Acoustic insulation, standardized level difference ($D_{2m,nT,w}$), the average SPL outside was 69 dBA, indoors with open doors and windows it was 60 dBA, when closing the door and window the interior SPL was 46 dBA, consequently, the façade insulates an average of 23 dBA. It is observed that the façades of classrooms B-201, B-301 and B-308, located next to the concrete walls, which are part of the building structure, having a rigid support, have a maximum insulation value of 32 dBA.

10. The double skin façade as a response to the noise problem

After studying the problem, two architectural solutions of installing a Double Skin Façade was proposed to reduce the effect of external-internal noise without affecting the original façade that reaches the AC, under the following conditions:

10.1 Proposal DSF

Place Double Skin Façade (DSF-THyAPIS), (Thermal Hydraulic, Acoustic, Photovoltaic, Solar Insulation), Figure 6, with a metal structure at 2.0 m, in front of the original façade of the building "B", "Façade of a Single Skin" (SSF) that is oriented towards Av. Insurgentes.

Advantages of DSF

- It will work as a noise reduction system [19], reaching the appropriate AC in the classrooms.
- It will provide a percentage of direct isolation from solar radiation.
- Allow passive ventilation to continue in classrooms.
- It will generate photovoltaic electricity.
- The support of the photovoltaic glasses will be with pipes so that the water flows through them, cooling the glasses and heating the water for various services.
- By generating electrical and thermohydraulic power, the initial investment can be amortized in a short time.
- Adds aesthetic value to the urban landscape, the "DSF", since it can be designed considering the type of structure, pipes, appearance and color the photovoltaic glass.
- It is Sustainable Architecture.
- The original façade is not affected.

Disadvantages of DSF

- Partially limits the views of Av. Insurgentes.
- The initial investment of the DSF-THyAPiS.
- Partially hides the original façade.

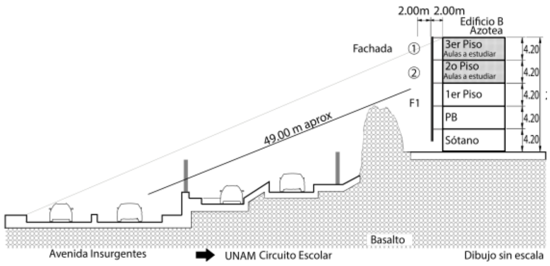

Figure 6 – Insulation acoustic with DSF-THyAPiS

Building B level and height of the DSF	SPL outside to 2 m from the SSF	Simulated value			SPL inside classrooms on the edge of the DSF	SPL inside classrooms between the Edge and the center of the DSF	SPL inside classrooms at the center of the DSF
		Edge of the DSF	Between center and the edge of the DSF	Center of the DSF			
2nd floor, DSF at 1 m above building B	68	56	52	50	32	28	26
3°rd floor, DSF at 1 m above building B	69	56	54	53	34	32	31
2nd floor, DSF at 1 m below the height of building B	68	56	53	51	32	29	27
3°rd floor, DSF at 1 m below the height of building B	69	58	56	56	35	31	32

Table 3 – Effects of DSF insulation at two heights

11. Results

To simulate the SPL generated by the vehicular traffic of Av. Insurgentes and measure it at 2 m from the DSF, as well as the SPL between the SSF and the DSF, the Predictor LimA Software [17] was used. This action had a double objective.

1) Simulate, using [17], the efficiency of the proposals.
2) Obtain data that allow the proposal to be evaluated prospectively.

The results are in dBA tables 3. To know the values within the classrooms, we use the values $D_{2m,nT,w}$ from Table 2.

12. Conclusions

Open doors and windows				
Qualifier	Average measured *In Situ*	ANSI/ASA S12.60-2010/Part 1	Status	Ideal
RT	1.27	0.6	Exceeds	> 0.6
BN	60	35 dBA	Exceeds	> 35

Close doors and windows				
Qualifier	Average measured *In Situ*	ANSI/ASA S12.60-2010/Part 1	Status	Ideal
RT	1.67	0.6	Exceeds	> 0.6
BN	46	35 dBA	Exceeds	> 35
Standardized level difference	28	dBA	Poor	35

Table 5 - Summary data by qualifier

After analyzing the summary data of the surveys in Table 5 and contrasting them with the tables, it was deduced that:

- The classrooms in building "B" are located outside the parameters established by ANSI/ ASA [16].

In order for the classrooms in building "B" to be within the parameter of the [16] standard, which indicates that the BN level should not be higher than 35 dBA, the solution was designed, which was corroborated with the [17], The results were:

- The DSF reduces noise, the average BN in classrooms is 26 to 35 dBA, complying with the [16] standard which is 35 dBA.

Therefore, the proposed DSF option is correct.

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