Acoustical project of the new Banca Popolare di Sondrio in Berbenno Service Center - I

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Abstract

North Italian Banca Popolare di Sondrio (NIBS) recently acquired an old industrial warehouse with the intention of obtaining its new Service Center; a multimedia space to host specific meetings, the board seat and a series of learning rooms for the various employees and office workers refreshing courses had to be carefully projected and realized in accordance with architect's requirements. Our engineering studio was entrusted with the architectural and PA acoustics projects of the shoe-box shaped room and the complete Audio-Video system. Iterative procesess through specific softwares leaded to the final design and realization. In this paper we will present the basic project acoustic requirements and the obtained results for RT_{60}, SPL, RASTI, D_{50} and C_{80} values. This paper does not focus on possible external disturbing noises and on the Audio-Video system.

1 Introduction

Post construction acoustic refurbishing is a known and complex subject. Many different constraints have to be taken into account, as for example external noise impact on internal acoustics, possible building modifications, architect's requirements and last but not least cost. Designing and building a structure from scratch is often simpler and mentally stimulating but the job in acoustic buros requires a lot of flexibility. Many constructions not originally thought and designed so that acoustics play a primary role, are subsequently adapted for specific uses where acoustics, audio and video become predominant. Even some famous original and very expensive realizations examples led to bad results, often due to the designer's excessive confidence. Let us solely cite here two of the most important: both the New York Philharmonic Hall realized in 1960 by Bolt Beranek and Newmann and the Sydney Opera House realized in 1973 by Jørn Utzon with more than $100.000.000 both proved to be acoustically very problematic if not disastrous. In the first case more than $2.000.000 were not enough to improve acoustics and in 1976 it was even necessary to completely demolish the interior of the room and redesign it from scratch [1], while for the second it has been necessary to resort to subsequent very substantial and expensive modifications for more tha $100.000.000, which will end this year [2]. So good acoustics is a challenging goal.

2 The room

The building NIBS acquired some years ago was an industrial warehouse. A complete refurbishing process had to be projected and managed regarding acoustics and audio-video multimedia installation spaces, to be able to host specific meetings, the board seat and a series of learning rooms for refreshing courses. The main shoe-box shaped hall is 31 meters long, 16m wide and from 7,5 up to 9 m high with a slightly wood pitched ceiling; the floor is characterized by 5 horizontal planes: the lowest for the speakers, a first slightly rising (3,5%) area for the audience, a horizontal plane for the main aisle, a second slightly rising (3,5%) area for the audience and a rear last horizontal plane taking to four exit doors, as showed in figure 1.

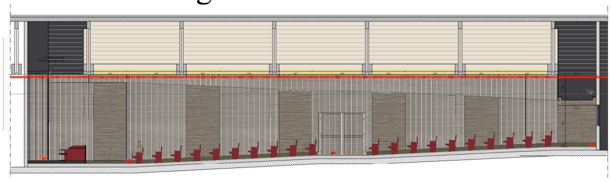


Figure 1. Side view of the main hall

The space is characterized by 540 seats. Audience is divided in 3 x 10 rows upwards and intersecated by a horizontal 3 m large aisle, which takes to the lateral double doors exits, so that 6 seat areas can be easisy defined, grouped by 3 in the direction of width. Every row has 9 seats and every area 90. The rear space is 2,5 m and the front 3,7 m up to the speaker's position.

Lateral distance from seats to walls is around 2 m and the inter-area distance is 2 to 3 seats, ie. 1,2 to 1,8 m. Seat dimension is standard 0,60 m and inter-row distance is 0,40 m; rows are slightly offset to allow better view, all showed in figure 2.

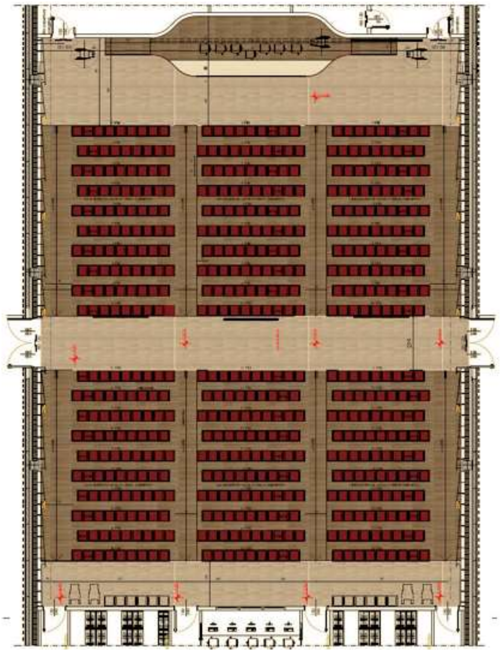


Figure 2. Floor plan of the main hall

3 Acoustical parameters

A mathematical software (Catt Acoustics) [3] was used to develop the most suitable solutions for the enclosed environment. This methodology has also been extended to the two main learning rooms, located on the building ground floor, while for the small rooms we relied on our simplified calculation software. The parameters we used to project and characterize the hall are the most commonly used in architectural acoustics, as shown in table 1, to which we added the Bass Ratio (LF).

Table 1. Acoustical parameters used in this project, with explanation and measure units

T10	Reverberation Time -10 dB (= EDT, Early Decay Time)	s
T15	Reverberation Time - 15 dB	s
T30	Reverberation Time - 30 dB	s
T60	Reverberation Time - 60 dB	s
SPL	Sound Pressure Level	dB
D 50	Deutlichkeit Faktor	%
C 80	Clarity Factor	dB
LF	Lateral Energy Fraction	%
STI	Speech Transmission Index	%

As regards acoustics in confined spaces, there is no specific legislation setting particular maximum or minimum limits for the main acoustic parameters. Each of them, despite having a scientific theoretical definition, is linked to subjective preferences, needs and objective evaluation and it becomes thus difficult to establish an univocal value. Our experience says that it is usually preferable to set an acceptability band for minimum and maximum values and the obtained results iteration process have to be evaluated on the basis of comparison ranges obtained from scientific literature and in the light of the experience and sensitivity of the acoustician. We based our choices on a series of values proposed by some main authors for a conference room with a 5,100 m^3 volume: auditoria Reverbetration Times up to -60 dB (RT_{60}): 0,9 s [4] 1,1 s [5] and 1,3 s [6].

The mentioned values are worldwide considered optimal for the intended use, from which it can be deduced that the RT_{60} in the central frequency bands 500-1000 Hz should ideally be around 1.0 to 1.2 s. Shorter RT_{60} mainly induce some improvements in speech intelligibility; longer RT_{60} are mainly considered good for musical performances.

A further need was a well controlled Bass Ratio or Warmth, i.e. the absorption curve (practically the inverse of RT_{60}) had to be almost constant over the entire audio band, except for the lower part of the spectrum, with a slight low frequency increase up to a maximum of 130% from the reference 1.000 Hz central band [7]. Too high deviations from these tolerances indicate too high absorption (or reflection) phenomena at certain octaves, creating reflected signal distortions compared to the original one.

The D_{50} values were evaluated in % according to the following criterion:

Table 2. D_{50} evaluative criterion in %

Optimal	D50 > 60
Acceptable	30 < D50 < 60
Not acceptable	D50 < 30

The reference values for C_{80} are the following: speech $\geq$ 3 dB and music $-4 \leq C_{80} \leq 2$ dB.

The LF obtained values were evaluated according to the following criterion:

Table 3. LF evaluative criterion in %

Good	15 < LF < 35
Acceptable	10 < LF < 15
Not acceptable	LF < 10; LF > 35

And last but not least, the STI values have been evaluated according to the following table:

Table 4. STI evaluative criterion in %

Insufficient	< 30%
Poor	da 30% a 45%
Normal	da 45% a 60%
Optimal	da 60% a 75%
Excellent	> 75%

4 The 4 phases

Phase I: model preparation. The first phase focused on the environment geometrical analysis and on the 3D model. The pre-existing structure is characterized by a hard wooden pitched ceiling, which has been considered untouchable by the architect, so our only possiblilty was to focus on the side and back walls. The side walls were subdivided in smaller surfaces, which were slightly tilted to achieve an absorbing-diffusing capacity at the various frequencies and the ceiling has been considered as a multiple scattering surface.

Phase II: surfaces acoustic properties definition. We defined the acoustic characteristics of the materials for each surface element, as well as the absorption coefficients α and the scattering coefficients σ for frequencies ranging from 125 Hz to 4,000 Hz. An iterative process provided a first generical response through CATT-Acoustic simulation software. Figure 3 shows the main lateral walls subdivision in smaller surfaces and their tilting final result process; each surface is visually characterized by a different colour showing the 2 surface materials: perforated wooden panels or sound-absorbing material covered with stretched fabric panels.

Phase III: sources and receivers definition. After another iterative process, the potentially most critical source-receiver combinations were identified. With this important information it was then possible to re-calculate the acoustic parameters of the room.

Phase IV: simulation. The software calculated the sound decay curves over time (echogram) and the acoustic parameters for each specified source-receiver combinations. In accordance with the initial results, it was then possible to adjust the model in order to correct any performance deficit and increase the acoustic quality. Some changes were necessary as from the client requests, in order to obtain good results without compromising aesthetics and architectural choices.

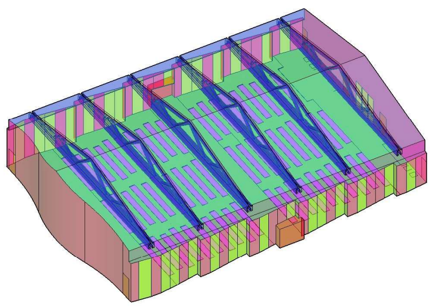


Figure 3. CATT-Acoustic simulation software 3D image of the hall: different colours define different absorbing-reflecting material

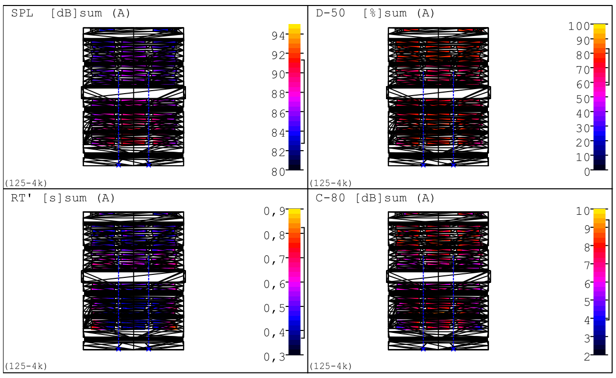
5 The sound source

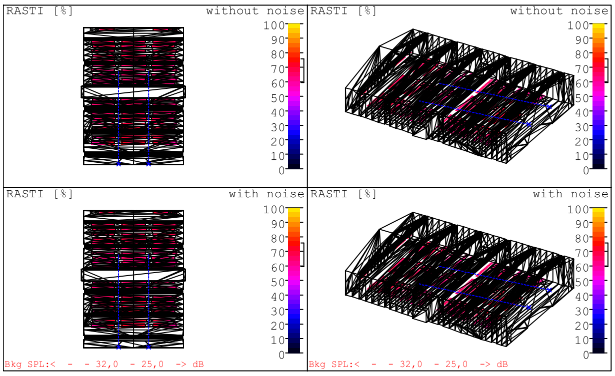
We considered a generic sound source with predefined directivity to take into account the audio system characteristics at an advanced design stage; we also considered two PA arrays installed on a truss above the speaker/ stage area. The client's request foresaw that the room would be mainly used for conferences and not for music, so we choose a voice signal as our main test sound signal. The average male-female spectral composition for a normal vocal effort is defined by the American standard ANSI S3.79 in terms of sound pressure level at a 1 meter distance along the source axis (Lp1m_a, expressed in dB), as shown in table 5:

Table 5. SPL average male-female spectral composition for normal vocal effort defined in ANSI S3.79

	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz
Lp1m_a	51.2	57.2	59.8	53.5	48.8	43.8	38.8	33.8

These levels have been prudently raised to approximately 85 dB at 500 Hz, while maintaining the energy ratios between the other octave bands. We also performed Full Detailed Calculation and Early Part Detailed ISM in order to discover the potentially most critical source-receiver combinations. Based on these data it was possible to identifie and calculate the final room acoustic parameters. Fortunately the possible critical reflected sound signals with a delay time higher than the "*echo threshold*" of 50 ms did not arise. A subsequent analysis was also carried out through Audience Area Mapping software. Figures 4a and 4b visually illustrate the acoustic parameters spread final results for the most significant source-receiver combinations.





Figures: 4a SPL D50, RT and C80 Acoustic parameters final results for the most significant source - receiver combination; 4b. RASTI Acoustic parameters final results for the most significant source - receiver combination

6 Final remarks

At the end of the iterative process all the D_{50} values resulted excellent (> 60%) and evenly spread over the listening area as well as the C_{80}, which were suitable for speech listening (> 3 dB). The Bass Ratio or LF values were only between 6 and 30%, very variable due to the too smooth untreatable wodden ceiling. This was compensated by very good and uniform STI and RASTI parameters across the whole room. The SPL value also appears within the recommended limits (-4/5 dB maximum) throughout the whole room.

In this paper we demonstrate that an attentive software implementation procedure and a good acoustician's evaluationis able to spring to good room acoustics for the needed purpouse.

Literatura

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