The new Teatro "Amintore Galli" in Rimini: Acoustic Design and Measurements on Diffusing Panels

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Abstract: - The acoustic design of sound quality in Italian-style theatres and opera houses normally included the study of the acoustic absorptions of tissues in the main hall, the measurements in reverberant room of sound absorption of seats, the acoustic design of the Orchestra pit, which could be equipped with several acoustic panels. Nevertheless, no particular care is normally devoted to solving the effect of focalisation that often occurs in these special buildings. The focalisation in these theatres could compromise the overall acoustic quality and for this reason should be considered and avoided. During this plenary lecture, a short overview about the meaning of focalisation and its presence in the theatres will be presented. After some recalls about the theory of scattering and diffusion and its measurements, some examples of acoustic design of diffusing panels will be introduced. Moreover, some experimental measurements of sound scattering and diffusion, made following the ISO 17497 procedure, will be shown. Finally, these theories and examples will be applied to the acoustic design of the new Teatro Amintore Galli in Rimini, north-East of Italy. The results of the measurements made on some particular diffusing panels which have been designed for this theatre will be introduced, as well as the comments of musicians, performers and listeners after the opening, that occurred the 28th October 2018.

Key-Words: - Room Acoustics; Teatro Amintore Galli; Scattering; Diffusion; Acoustic Quality; ISO 17497

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1 Introduction

The town of Rimini, North East of Italy, has opened the 28th October 2018 new Teatro "Amintore Galli", which was partially damaged in 1944 during the Second World War and afterward demolished. The new theatre recalls the original architectural idea of the existing theatre (designed by Luigi Poletti), but improves the technological equipment, including noise insulation and acoustic quality. However, some constraints have conditioned the original acoustic design, especially the new archaeological area that was inserted underneath the ground floor, which required to change the original wooden structure into a concrete-based one.

The acoustic design of sound quality included the study of the orchestra pit, the acoustic absorptions of tissues in the main hall, the measurements sound absorption of seats. Since the shape and the characteristics of the material (marmorino, stucco), might have caused focalization, a special care was reserved to design diffusing panels located in the main hall.

This paper focuses on the acoustic design in the theatre, especially considering the diffusing acoustic panels inserted in the main hall. Starting from the drawings, the paper will examine the results of the scattering and diffusion measurements on the panels, as well as the overall sound quality of the theatre after the opening of October 28th, 2018.

2 The Theatre Galli in Rimini

The theatre was designed by Luigi Poletti from Modena, an architect who designed several buildings within the Pontifical States, and opened August 16th, 1857. The theatre had a semi-circular shape, similar to the horse-shoe shape that characterises many other Italian theatres, and it could host about 800 people. Perhaps one of the most interesting characteristics of the theatre was the number of columns between the second and third order of the boxes, which was a typical aspect of Poletti's design.

The photograph taken in 1910 shows a very crowded hall, both in the stalls and in the boxes, and maybe the theatre in some cases could also host much more than 800 people. Perhaps, the high number of people could compensate the reverberation that it might be in the empty room, and the focalisations caused by the reflecting walls around the stalls at the first level.

2.1 The history of the reconstruction

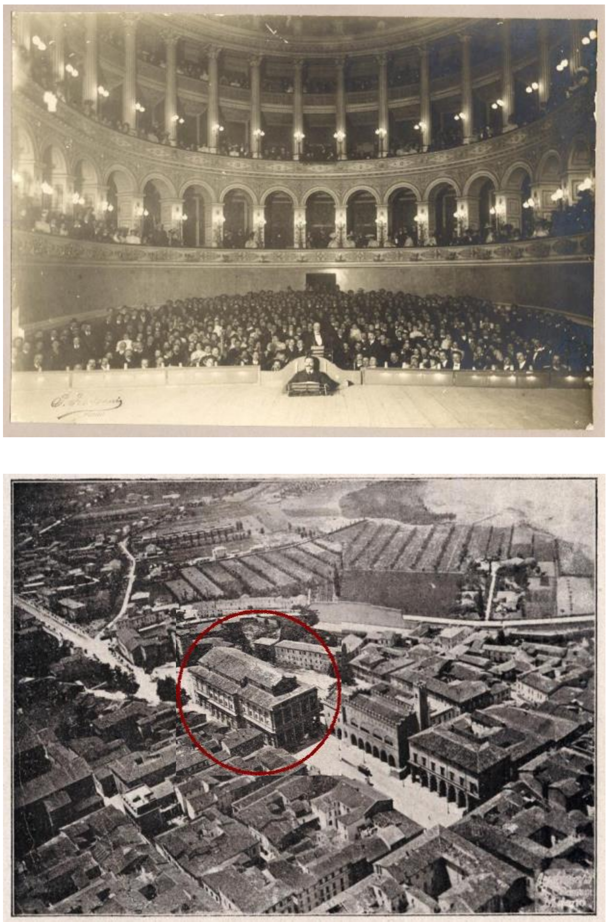

Fig 1 – the original theatre in 1910 (above) and 1925 (below)

After the air attack in 1944 which damaged the main hall of theatre, whereas the foyer was only slightly injured, the area of the theatre was temporary transformed into a gym, and any further decision about the theatre was postponed.
Since the 1950s, when Rimini became the most important and populated coastal centre in Italy, the local Municipality started a debate which involved the most outstanding cultural personalities of the town, about the reconstruction of the theatre. For many years a long debate involved not only the inhabitants of Rimini but all the cultural community of Northern Italy, in order to decide which could have been the suitable solution for the theatre.
In 1995 an International competition for the new theatres was launched. The final project that was chosen (arch. Natalini et al) proposed a completely new theatre, totally different from the Poletti theatre of 1857, but immediately a large number of cultural personalities expressed their concerns of the project. At the beginning of the new millennium, accordingly with the Regional and National authorities on cultural heritage (the Regional Superintendence and Ministry of Cultural Affairs), a new project was developed, following the rule “as it was, where it was”, in the same way as the theatres Petruzzelli in Bari and Fenice in Venice were rebuilt after the burning. This induced to develop a totally new project for the theatre.
Accordingly, the new project had to take into account all the technical requirements that a new theatre requires about acoustics and safety.

3 The acoustic design

The acoustic design has involved different aspects in the theatre, including sound insulation and acoustic quality: the most relevant on sound quality are the realization of the orchestra pit with variable acoustics, the modelling of the vibrating ceiling in the main hall, and the introduction of acoustic panels in the cavea, i.e. in the boxes and on the incoming doors in the stalls, for improving sound spatialization and diffusion in the main hall.

3.1 Sound insulation

As far as building acoustics is related, the design of the new building was developed with the purpose of reaching high acoustic standards, but maintaining a low global cost, using technologies and materials highly performant and at the same time easily available on the local market.

Target values for sound insulation in the Theatre (dB)				
R_W	$D_{2m,nT,w}$	$L_{n,w}$	L_{Aeq}	L_{ASmax}
53	45	52	30	30
50	42	55	35	35

Tab 1 – Target value (above) and minimum law requirements (below) for the Theatre

In order to guarantee such high level of sound insulation, several specific packages have been calculated and designed, especially for some critical situation, like the sound insulation between the rehearsal room and the main hall. As far as this floor is regarded, the upper structure is suspended over metallic elements (“omega” structures), in order to let the floor itself to vibrate elastically at very low frequencies (below 50 Hz).

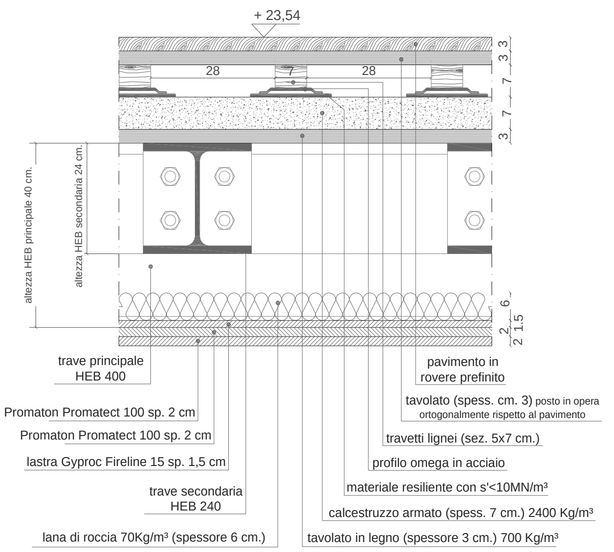

Fig 2 – the floor between the rehearsal room and the main hall

3.2 Acoustic quality

The reconstruction of the theatre followed the role: “as it was, where it was”. To properly design the acoustic quality in the theatre, an important preliminary task was to assess how the acoustic quality was before the destruction, similarly to the reconstruction of the theatre La Fenice in Venice, where the starting point of the acoustic design was the acoustic campaign made by Tronchin in 1995 [2]. However, in this case obviously no acoustic data were available. In order to foresee the acoustic intentions of Poletti, it is interesting to consider the opinions of Francesco Milizia (1725-1798), who wrote in 1794 a book “del Teatro” in which he described the characteristics of the ideal theatre [3]. Milizia had a great influence on the Italian architects, and for this reason presumably Poletti knew Milizia’s work.

One other key factor for assessing the acoustic characteristics of the Teatro Galli before its destruction was the analysis of other similar theatres. Poletti designed other two theatres during his life: one in Terni (“Teatro Verdi”) and the other in Fano (“Teatro della Fortuna”). The Teatro Verdi was damaged during Second World War and reconstructed completely different from the original Poletti theatre. In Fano, the “Teatro della Fortuna”, after being itself damaged during the Second World War, was renovated in 1998 but following the original schemes drawn by Poletti.

For these reasons, in 2009 a campaign of experimental measurements in the “Teatro della Fortuna” was undertaken, as shown in figure 3, following both ISO 3382 standards and the new methods described by [4,5]. The information gathered during the measurements were used to finalise the acoustic design and underlined the importance of solving the focalization in the stalls.

Fig 3 – Measurement in Teatro della Fortuna, Fano

After the acoustic design made by means of the numerical model (Ramsete), the following table 2 was obtained; it reports the final target values (average) for the theatre, for all the different configurations (symphonic music, opera, speech).

Frequency, Hz	63	125	250	500	1k	2k	4k
T20	2.7	2.0	1.6	1.5	1.6	1.5	1.1
EDT	2.2	1.6	1.3	1.2	1.2	1.1	1.0
C50	-2.2	-0.7	0.5	1.0	1.0	1.2	2.6
C80	-0.1	1.4	2.6	3.1	3	3.1	4.7
D50	37.6	45.8	52.9	55.9	55.8	56.7	64.8
Ts	142.2	103.9	82.5	75.1	75.8	73.4	54.9
G	5.1	3.8	2.3	2	2.1	2	1.3
RaSTI		0.65	0.69	0.7	0.7	0.7	0.75

Tab 2 – Target values for the Theatre

4 Design of sound diffusion

The most important aspect of the acoustic design of the new “Teatro A. Galli” consists on the evaluation and design of specific acoustic diffusors in the main hall of the theatre. Two different typologies of acoustic diffusors have been specifically designed: the first on the boxes, and the second on the five doors accessing to the stalls, in the main hall. These devices will allow to obtain a condition of diffused sound field, that is particularly desired in concert halls and theatres, and will avoid focalization installs and boxes, that are very often found in Italian-style Opera Houses.

4.1 The diffusing panels

wo models of diffusing panels have been designed for the boxes and for the stalls, starting from the well-known Schröder theory. Figure 4 and 5 report the sketches of the two panels. For the new Teatro “A. Galli”, the panels in the boxes were designed with the sequences of quadratic residue obtained from numbers 13 and 17.

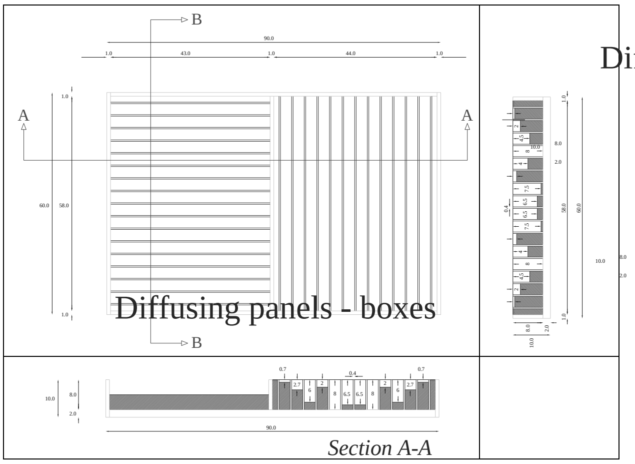

Fig 4 – Diffusing panel in boxes

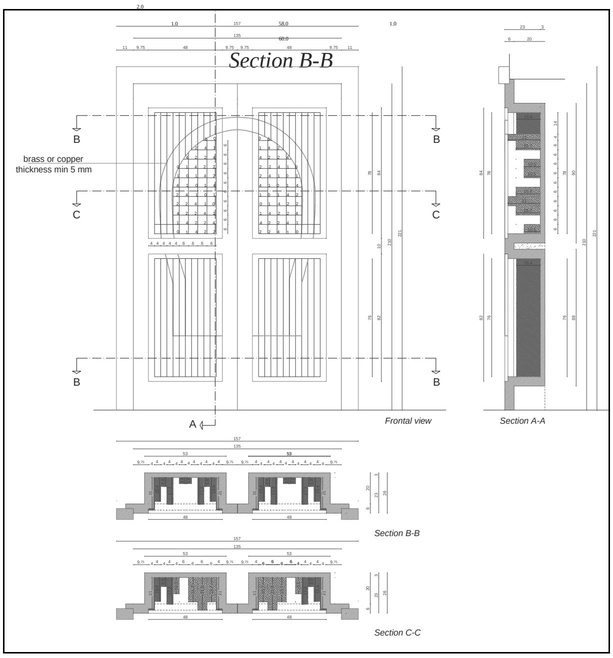

Fig 5 – Diffusing panel at the main doors

5 Measurements of sound diffusion

In order to measure sound diffusion as reported in ISO 17497 part 2, the following equipment was utilised:

- 25 prepolarized Brüel&Kjær 4188 microphones with 2671 preamplifiers (phantom-powered);
- 4 8-channels Behringer AD-DA 8000 Converters;
- 1 audio interface firewire M-Audio “Profire Lightbridge”
- 1 Genelec “8351 SAM” sound source

Fig 6 – Measurements on the diffusing panel

As required by the standard, the single reflection response is obtained by subtracting the two impulse responses h_1-h_2, this rejects most of the direct wave and spurious reflections.
The actual reflection (h4) is then found by deconvolving the system response by division in the frequency domain:

$$h_4 = IFT\left[\frac{FT[h_1 - h_2]}{FT[h_3]}\right]$$

The first two impulse responses must be time windowed at the first reflection arrival: the time window start was initially decided by visual inspection as suggested.
After division in the frequency domain, a frequency window was applied to the data, to cut off all of the high frequency discrepancies due to time windowing; this operation was considered necessary after inspection of the single tracks. The diffusion coefficient was then calculated from the reflected sound pressure levels using the equations reported in the ISO 17494 Part 2:

$$d_\theta = \frac{\left(\sum_{i=1}^{n} 10^{L_i/10}\right)^2 - \sum_{i=1}^{n}\left(10^{L_i/10}\right)^2}{(n-1)\sum_{i=1}^{n}\left(10^{L_i/10}\right)^2}$$

Where Li = sound pressure level of the i-th receiver, n = number of the receivers.

The experiments were conducted to test the diffusing panel for the Teatro "A. Galli" located in the boxes. The measurements were conducted with different position of the panel, to test its quality in each position. The experimental data were used to fit a theoretical model of reflection, so to extract diffusion coefficients that can be used in an acoustical modelling software:

$$I_{diff} = \int_{y=-b}^{b} \int_{x=-a}^{a} \frac{W \cdot z_c}{4\pi \cdot r_1^3} \cdot \frac{(1-\alpha)\cdot \delta_{loc}}{2\pi \cdot r_2^2} dx \cdot dy$$

where: W is the source's power;

z_c the distance between source and the centre of the panel;

r_1 the distance between the source and the a*b portion of the panel;

r_2 the distance between the panel and the receivers;

α the absorption coefficient

Moreover, δ_{loc} is the computer program diffusion coefficient which increments to 1 as the surface particle in exam gets near the panel's border.

$$\delta_{loc} = 1-(1-\delta)\frac{2\cdot d_{min}}{\lambda}$$

Fitting the value of W on the filtered measurement data of pseudo intensity, the solver function was used to automatically optimise α and δ to maximally match the reflected pseudo intensity values.

The figure 7 reports the optimisation.

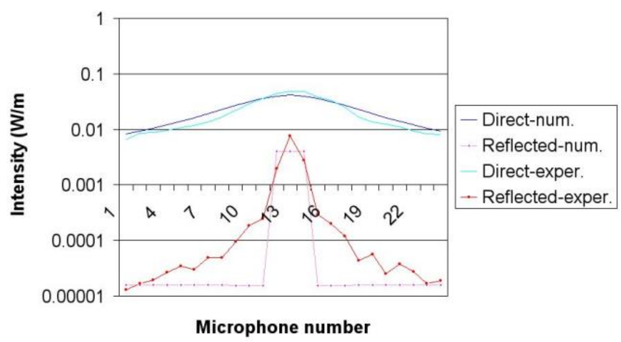

Fig 7 – Optimisation of α and δ

6 Results

The graphs in figures 8 and 9 report the comparison among the different 5 configurations considered. The dotted line reports the values of the reflecting panel (alone), whilst the other lines report the values of the 4 configurations which include the diffusing panel. The red, bold, line reports the values related to the panel in the configuration effectively used in the theatre.

From the graphs, the scattering coefficients (figure 8) resulted higher than 0.8 for all the frequencies, except for 250 Hz (the scattering value is 0.72) and 500 Hz. At this frequency, all the configurations showed a lower value, and it might be caused by the effect of the wall already descripted earlier. It is evident the difference between the reflecting surface (dotted line) and the other 4 configurations which included the diffusing panel

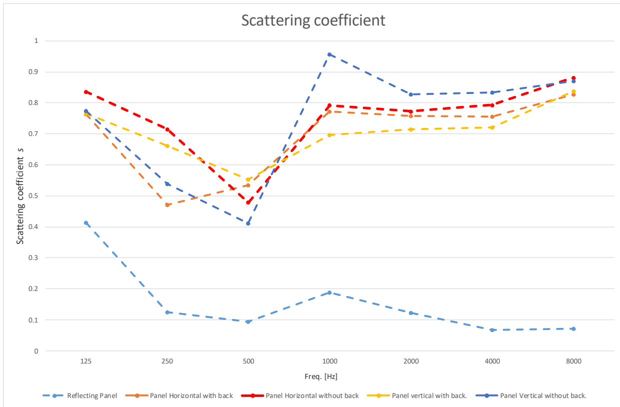

Figure 8 – Comparison among scattering coefficients

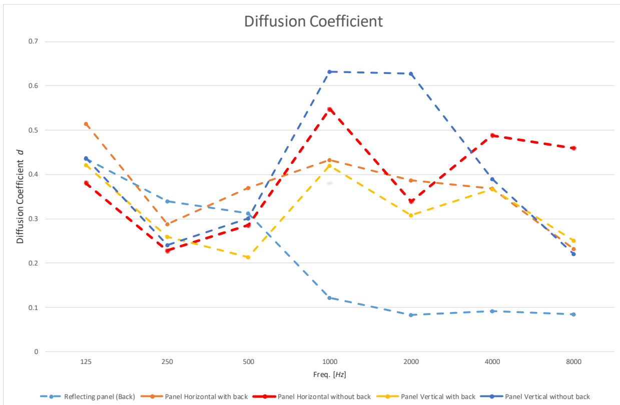

Figure 9 – Comparison among diffusion coefficients

On the other hand, figure 9 reports the results of the diffusion coefficients. In this graph the effectiveness of the diffusing panels appears clearly starting from 1 kHz, where the reflecting surface shows no diffusion, whereas the diffusing panel is much more diffusing. For these reasons the use of the diffusing panels located in each box could be useful for increasing diffusiveness in the boxes.

7. Conclusions

The paper showed the results obtained after the measurements of diffusion and scattering coefficients for a specific diffusing panel designed for the Teatro "A. Galli" in Rimini which has been inserted in each box for the first three levels. Starting from the graphs, is was possible to assess the effectiveness of the panel with reference to the scattering and diffusion coefficients. The values obtained give a proper description of the diffusion and scattering coefficients, which are considered quite important to reach the highest value of spatiality and diffusiveness in a theatre.

In the next future, the experiments will include the measurements on the diffusing panels located in the entering doors, which consists of two different parts (QRD and RPG panels), reported in figure 5. These panels represent the first attempt to solve the focalization often found in the stalls of Italian-style opera houses. The first impression after the opening of the theatre (28th October 2018) were enthusiastic for the acoustic quality of the main hall, as reported both Cecilia Bartoli and Valery Gergiev.

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