

# REBUILDING OF AN ORCHESTRA REHEARSAL ROOM: COMPARISON BETWEEN OBJECTIVE AND PERCEPTIVE MEASUREMENTS FOR ROOM ACOUSTIC PREDICTIONS

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## 1 INTRODUCTION

The acoustical conditions of rehearsal rooms are of great importance for orchestra training. In those specific spaces, both performance and working acoustical conditions are expected, but there is no guidance of operations for designing such a space.

La Sirène de Paris is a cultural association whose principal activity is music. Its residence is a trapezoidal rehearsal room whose volume is about 1150 m<sup>3</sup> situated in Paris 14th district. This paper presents the care taken by acoustical consultant IMPEDANCE SAS in the rebuilding project and the relocation of the association in the building infrastructure.

The most attention is paid to the correlation of user's perception of the actual acoustical characteristics of the rehearsal room by comparing a subjective study with objectives physical measurements. The sound exposures of orchestra players are taken into consideration. A study of other rehearsal room indicated by the users as being good for orchestra practice is used. Aiming for the reproduction and improvement of acoustical conditions of training for the orchestra musicians in the new rehearsal room, results show the correlations between perceptual and objective measurements and the relation between requested acoustical characteristics and design issues.

## 2 CONTEXT

## 2.1 Presentation of La Sirène rehearsal room

The room is situated in Paris 14th district. Its shape is trapezoidal with a volume of 1150 m<sup>3</sup>, an area of 200 m<sup>2</sup> and a gauge of 150 persons. Figure 1 shows the ground floor of La Sirène. Actual room acoustic furniture of the room is absorbent ceiling; wooden lath and plaster coating wall; linoleum and parquet floor. One can note the presence of a balcony of 10 meters long on one side of the room and a rounded wall at the entrance side.

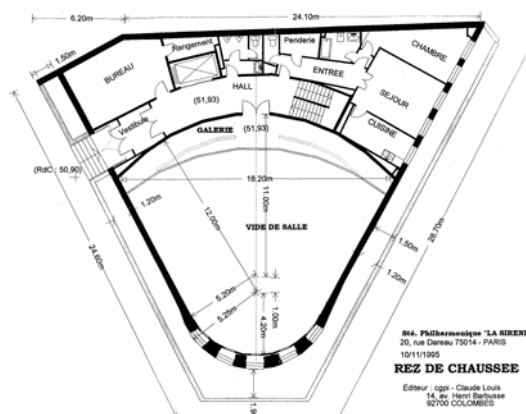


Figure 1: ground floor of La Sirène room

## 2.2 Literature Study

Following authors examined for better working conditions in rehearsal rooms. Drotleff<sup>1,3</sup>, Fuchs<sup>1,3</sup>, Gade<sup>2</sup> and Zha<sup>1,3</sup> present acoustic measurements in rehearsal room and suggest acoustical design and indices as follow:

- Flat reverberation time range from 0.5 to 1 second
- Clarity in the order of 6 to 10 dB
- 70% of the ceiling with random oriented high reflecting panels to improve cross communication between musicians
- Achieve an equivalent absorption area of 8 m<sup>2</sup> per musician to avoid high levels
- Acoustic levels must be low to avoid irreparable hearing damage to users
- Wall behind musicians and chef must be absorbent to avoid detrimental reflections
- Lateral walls should be absorbent from upper part but reflective in lower part
- Get diffuse reflections from room boundaries
- Strongly increase low frequency diffusion to homogenize acoustic field.

## 3 ROOM ACOUSTIC CHARACTERIZATION

A room acoustic characterization has been done on January 2014. Table 1 shows the acoustical criterion of the empty room averaged for 10 pairs of source-receiver positions and measured in octave bands with respect to the NS EN ISO 3382-1:2009 - Acoustics "Measurement of room acoustic parameters" Part 1: Performance spaces.



Figure 2: photography of La Sirène room

Exponential sine sweep signal<sup>4</sup> technic with a ST250 B-format Ambisonics microphone and an Outline G.R.S. dodecahedron omnidirectional speaker have been used as equipment to perform the measurement. Figure 2 shows the equipment during measurement in La Sirène. Post treatment was carried out with OpenMIDAS software<sup>5</sup> to obtain room acoustical criterion presented in table 1.

Freq. (Hz)	EDT (s)	TR30 (s)	C80 (dB)	D50 (%)	ST1 (dB)	Tc (ms)
62	1.2	1.6	2.5	45.8	14.3	91.0
125	0.9	1.2	4.8	56.5	-2.9	62.3
250	0.7	1.0	6.5	63.9	-3.8	47.6
500	0.8	0.9	6.2	62.9	-3.8	49.4
1000	0.9	0.9	5.0	59.0	-3.0	56.0
2000	0.8	1.0	5.9	63.9	-7.8	49.3
4000	0.7	1.0	6.9	69.7	-4.3	41.8
8000	0.4	0.7	11.0	82.4	-10.5	23.4

Table 1: acoustical criterion of La Sirène rehearsal room (empty)

Results show that reverberation times EDT and TR30 values are relatively high for orchestra training. Those values are homogeneous in the range 250 to 8000 Hz but poor performance can be seen in the extra-low frequencies as for other criterion. On the contrary, Clarity C80, central time Tc and definition D50 are low for orchestra training, indicating the same trend, that is to say the room let too much sound energy in the late reverberation. At last ST1 criterion is high and does not favor cross communication between musicians. All values should be suitable to perform orchestra music excepted for low frequencies.

## 4 MEASUREMENT

### 4.1 Perceptive study

Perceptive study was conducted on 70 musicians who frequent the room. 51% of them are professional, 57% frequent La Sirène more than once a month, 84% for more than a year, 9 different orchestras answer but 3 of them represent 81% of the answers. Users were asked for their perception of the acoustical behavior, music balance and dynamic of the room. Semantic issues are discretized in five scale from weak/low (-2) to loud/high (2). Questionnaires were broadcast both in paper and digitally. Results are presented in the figure 3.

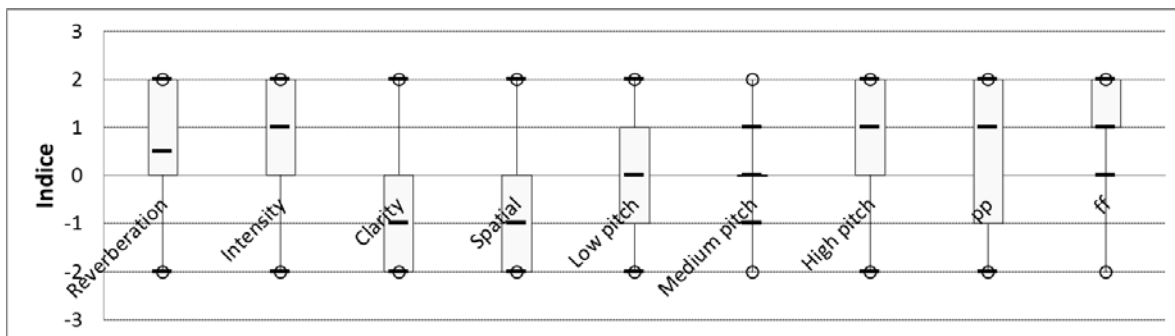


Figure 3: perceptive results of the test conducted on the users of La Sirène

According to the users, reverberation is considered rather large, as intensity, which is equivalent to natural amplification of the room. Moreover, spatial organization of the sound as clarity is evaluated as low. Medium pitch is evaluated as good but low pitch evaluation was better than expected. At last, high pitch, fortissimo and pianissimo are felt as loud. Poor global acoustical quality comes out of this perceptive study, in good accordance with room acoustic characterization measurements.

### 4.2 Objective study

Four recent rooms of good reputation have been selected on several criterions from architectural similitude to references from users: Bondy Auditorium (3270 m<sup>3</sup>, dedicated to vocal ensembles); rehearsal room of Municipal Conservatory of 17th district of Paris - CMA17 (1090 m<sup>3</sup>); rehearsal room of Conservatory of Levallois (960 m<sup>3</sup>); rehearsal room of RATP cultural center (1200 m<sup>3</sup>). Measurements were made using an ST250 B-format Ambisonics microphone and balloons as impulse sources. Post treatment was done using OpenMIDAS software. Figure 4 presents the results.

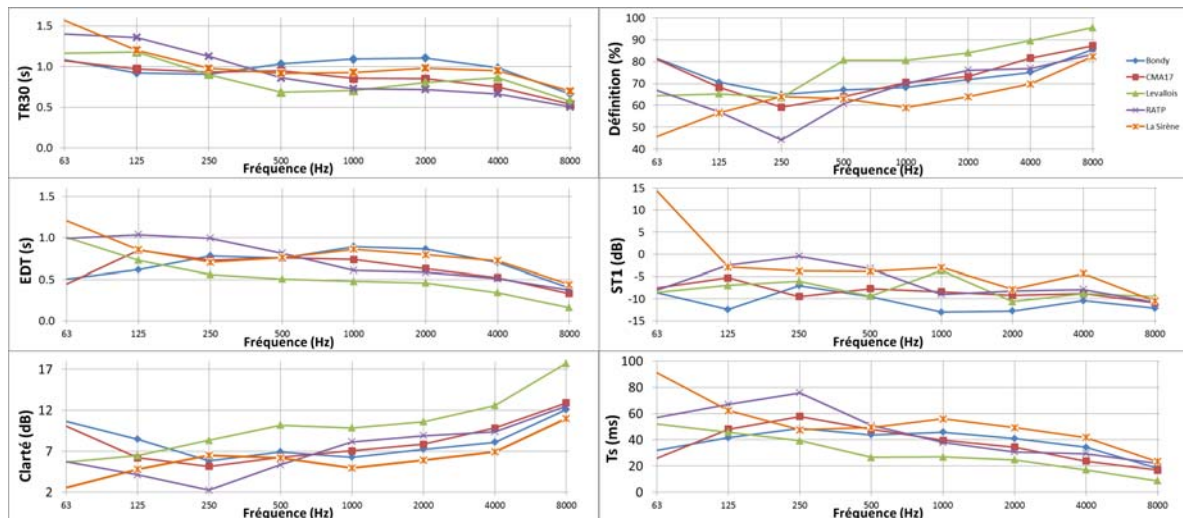


Figure 4: acoustical objective measurements in four rehearsal rooms

Considering reverberation times room acoustic criterion, most results are lower in comparison with La Sirène. At the contrary but in the same trend, results are higher for energetic criterion. It shows a suitable acoustic for orchestra training in most of the visited rooms. Stage support ST1 value, concerning cross communication between musicians, goes in the same direction.

Good results in Bondy, Levallois and CMA17 may be favored by the presence of diffusors panels covering the walls. One can note that from 2000 Hz La Sirène has always the worst results. At last, the presence of a bleacher in most of the visited rooms supports sound balance of the orchestra. It may be observed that bleacher's dimensioning is important: at RATP, equipped with a bleacher with great spans between each step, undesirable time delays occur across the orchestra.

## 5 COMPARISON

### 5.1 Perceptive and objective results show a good correlation

Results show that users of La Sirène experience a high reverberation time and high intensity. Measurements revealed that La Sirène has higher EDT and TR30 than the other rooms except Bondy (a singer's rehearsal room) and show the flattest and smoothest TR30 and EDT. Furthermore, users of La Sirène complain of a low clarity and spatial confusion, confirmed by poor clarity (C80) and definition (D50) scores. At last, users judge that the sound is well balanced except for the high frequencies, what we translate in a non-homogeneous behavior in respect with frequency.

## 6 TOWARD ACOUSTIC BRIEF

Precedence is given to symphonic and harmonic orchestra training. Removable bleacher network are provided to raise percussions and few wind musicians. Regarding the shape of the room, musicians should be backside to the entrance. This configuration is already used by most of the users when numerous musicians are present in the room. Although room volume of La Sirène will increase from 1150 to 1500 m<sup>3</sup>, it will still be insufficient to combine an accurate TR30 with an acceptable sound level when a full orchestra (up to 90 musicians) is rehearsing in the room. If we followed Gade's criterion of equivalent absorption area of 8 m<sup>2</sup> per musicians it would result in a very low TR30 of 0.5 s. Based on the subjective appreciation of La Sirène staff at Levallois rehearsal room and on our own measurements, a fair balance between a rather low TR30 and a comfortable sound level can be achieved with a TR30 of 0.7 s and an equivalent absorption area of 350 m<sup>2</sup> (4 m<sup>2</sup> per musicians for a full 90 persons orchestra).

A computer modelling has been done to project room acoustic criterion of the refurbishment of La Sirène room in respect with the acoustic design recommended.

## 6.1 Room acoustic design

Reflecting panel network will be provided at 4 meters high. Those square panels of 2 meters side and spaced of 50 cm will be inclined in 4 different directions with a 5-degree angle to improve cross communication between musicians with a diffuse reflecting effect. Ceiling will be covered of broadband acoustic absorption fiber wool, as well as upper part of lateral walls (in beige in the figure 3). Moreover, wall situated in front and behind of the orchestra will be covered with wood perforated panels with a 30 mm plenum fulfilled with mineral wool (in orange in figure 3). At last, two types of diffusors will be provided at lateral sides in low part of the wall and in front of the low part of perforated wood absorbing panels. First type, provided a plenum filled with mineral wool, will also provide low frequency absorption.

## 6.2 Modelling

To confirm the accuracy and reliability of the acoustic treatment recommended, a computer modelling of La Sirène room refurbishment is made with the help of CATT-Acoustic software. Ray-tracing prediction method is conducted within TUCT associated algorithms. Figure 5 shows the computer modelling of La Sirène refurbishment.

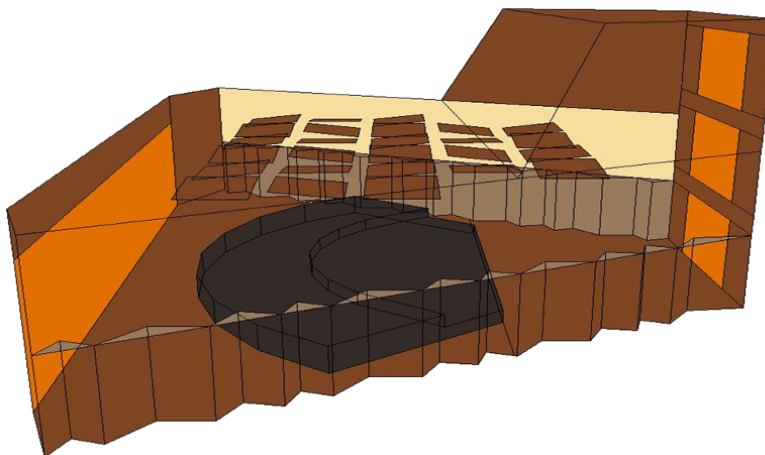


Figure 5: CATT-Acoustic modelling of La Sirène room acoustic recommendations

## 6.3 Results

Results of the computer modelling are presented in table 2.

Freq. (Hz)	EDT(s)	TR30 (s)	C80 (dB)	D50 (%)	Tc (ms)
125	0.5	0.6	9.4	72.4	36.3
250	0.5	0.6	9.6	76.2	36.2
500	0.5	0.6	6.9	74.9	37.7
1000	0.7	0.6	5.5	64.8	46.8
2000	0.6	0.7	7.7	74.3	38.4
4000	0.6	0.6	8.5	74.6	36.6
8000	0.5	0.5	11.3	82.6	27.6

Table 2: acoustical criterion results of La Sirène CATT-Acoustic simulation

Projected calculation results show low and flat broadband reverberation times as expected. Low frequency values became performant for all criterion corresponding to an intensively use of diffusor panels. We can see good results for energy acoustic criterion since values behavior are relevant to those measured in Bondy and low frequencies values are close to Levallois.

## 7 SUMMARY

The rebuilding project provides the relocation in the building infrastructure of the association La Sirène de Paris. Perceptive and objective measurements have been done to characterize the acoustic of the rehearsal room. In parallel, we compare acoustic indices of four rooms chosen for their acoustic qualities.

Aiming for the reproduction and improvement of acoustical conditions of training for the orchestra in the new rehearsal room, results show good correlation between perceptual and objective measurements. The relation between requested acoustic characteristics and design issues leads to the modeled design with results are good compared to expected ones.

## 8 REFERENCES

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