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ACOUSTIC PROBLEMS OF THE SALLE PLEYEL(PARIS) AND THE MODIFICATIONS IN 1994

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1.HISTORICAL BACKGROUND

The rare concert hall of 3000 seats in Paris,"Salle Pleyel", was inaugurated at October 10th 1927(architects : Auburtin, Granet,Mathon; acoustician : Gustave Lyon). Its quassi-cylindrical parabolic shape(**Figure 1**) is formed by the concave plaster(3cm) ceiling and the tilted,curvilineal side walls(in hollow brick 5cm with concrete frame). Even it was a fire in Salle Pleyel in 1928,after that event,Ravel,Stravinsky, Prokofiev,Rubinstein and Heifetz had played there enthusiastically. However,the high directional sound projection towards the audience was the "modern" conception of that time.

In 1961,many modifications had been effected in this hall,such as : the extension of the stage,the suspension of the reflectors(with diamond reliefs) above the stage,the inclination of some rear walls and adding the absorbing materials on certain walls and floors. The number of seats was reduced under new standard.Due to the multipurpose requirement,the height of the stage ceiling became very low. The measured reveberation time (RT60) in the empty hall was only 1,65 sec.(500Hz,**Figure 2**).

In 1981,the important modifications were executed(architect: Hamayon,Rosset; acoustician:Melzer; scenogrphe:Guillaumot).The stage was further extended to 350m², the carpet was replaced by wooden floor,the ceiling shape was returned to the original "parabolic" profil but patially(30%) in movable wood panels (above the stage),~50% in wood strips(2cmx5cm and 7,5cm empty, ~2,5m below the plaster ceiling) and ~20% in plaster(above 2nd balcony). The rear part of the stage enclosure is only 5,0m high,the height of front stage is only 10,7m. The space above the stage enclosure is occupied by the structure,ducts,scenary machines,so the movable panels can not be raised any more. Once again,nevertheless,the multipurpose requirement was over-considered in the 1981's renovation with the expense of many acoustical defects for the musical performances.

Although the RT60 of the empty hall was raised to 2,2 sce.,but the occupied RT60 is still 1,6 seconds. As the Salle Pleyel is the only large concert hall(2386 seats) used for the classical music(90%) in Paris,therefore,the acoustic problems have to be resolved. The main acoustic problems are :

-Excessive frontal reflections with harsh sound perception

-Poor balance between the strings and the brass/percussion

-Lack of lateral diffusion due to the large smooth walls

-Long delayed reflections due to the tilt,curved side walls

-Echo on the rear part of the stage

-Reverberation time is not long enough

The author had studied the acoustic characters of Salle Pleyel right after the 1981's renovation. In spite of the advantage of its narrower plan,the low and steeply tilted stage ceiling and the smooth side walls provoke a series of drawbacks.

In 1989-1990,CSTB and Xu had continued the acoustic diagnosis for the Salle Pleyel. The computer simulation and the 1/20th scaling model test(CSTB) had been done,a proposal on acoustics and architecture had been prepared with the architect(Yves Le Jeune). But,it was laid down in the drawer afterwards.

Until 1994,the owner of Salle Pleyel had appointed Portzamparc (architect) and Xu to make a new proposal under a limited budget. The following description is dealing with the first phase modifications done in the summer of 1994.

2.TECHNICAL SOLUTIONS IN 1994

2.1 Stage ceiling and the wood strips ceiling

The excessive frontal reflections are caused by the smooth and steeply tilted stage ceiling.The sound of brass and percussion groups is over-reinforced by the ceiling panels(wood) nearby. Inversely,the sound of 1st violins can not be reflected by the stage ceiling(due to the location and the directivity),it is partially penetrate into the 60% opened wood strips and then it is dispersed within the upper space. The brilliance of the string's sound is darkened,the balance of orchestra is poor.

When a sound source is too closed to a large,smooth reflector, the comb-filter effect and the sound distortion is occured.One can hear oftenly the aggressive sound during the "fortissimo" of the brass,but in Salle Pleyel,we can hear the harsh sound even for the woodwind instruments. Because the strong specular reflection,the different timbres can be percieved from one area to another. Due to the slope of the stage ceiling,the mutual hearing is difficult for the musicians located at the rear part of the stage.

In consequence,the modifications for the ceiling in 1994 are :

(A)Replacing the 3 big flat ceiling panels by 3 light weight Maximum Length Sequence (MLS) diffusors. The depth of the MLS diffusor is 8cm,the estimated effective diffusing band is around 800~1600Hz;may be in reality,it could be extented until higher frequencies. **Figure 3** shows a polar pattens of the scaling model of the MLS diffusor(N = 15).

Because the diffusor is made by Alucobond(sandwich panel,4mm) with higher damping factor,its folding profil has also higher stiffness,so the absorption coefficients of the MLS diffusors are quite reasonable(shown in following table,meausred in the Reverberation chamber) :

Frequency(Hz)	125	250	500	1000	2000	4000
Alpha	0,084	0,066	0,077	0,058	0,078	0,083

Owing to the diffusing ceiling,the specular reflections(high/ middle frequencies) is split in "time" and in "space". The sound distribution on the stage and in the audience area is improved. Therefore,the unfavorable,existing steep angle of the stage ceiling could be more and less compensated.

(B)Two stage ceiling panels above the percussion and brass are tilted more vertically. This "opening" could release certain sound energy of the powerful instruments. The 5cm SONEX foam is glued on the back of each panel in order to adjust further the orchestra balance.

(C)Two large pieces of the wood strips ceiling(60% empty) are covered by the flat Alucobond panels(5,5kg/m²). This sensitive part of ceiling(for violins) is no more "trasparent". The length(longitudinal) of the new reflectors is 7,5m,the solid angle(energy raiation) is about 20°(counted from the 1st violin's position). The reinforced string sound and the more brilliant tone are perceptible.

2.2 Side wall diffusing treatment

The original side walls are curved and tilted inwards(~12°) to the hall. The impulsive sound from the stage can be reflected horizontally around the walls,the long delayed reflections provoke the repeated notes of piano and so on. Besides that, the large smooth wall produces a unnatural sound perception. Sometimes,one can perceive the wrong sound image localizition.

The applied solution is to install the acoustic diffusors on the lower part of the side walls,the average height of the staggered diffusors is 5,0m. They are tilted following the existing 12° inclinaition of side walls. As shown in **Figure 4**, they are composed by the MLS diffusor on one side,a flat panel on the other side. There is a vertical slit between two diffusors where architect inserts the grazing decorative light. In order to diffuse the sound in a wider frequency band,three different dimensions are proposed for the MLS diffusors :

width of MLS(1 period)	120cm	180cm	225cm
Depth/diffuse freq.	8cm/1062Hz	12cm/708Hz	15cm/566Hz

Due to the low-end diffusing frequency of MLS is limited by the depth,so the large geometrical(zig-zag) diffusor becomes necessary. The apex of the wedge(in plan) is about 40cm and the average hypotenuse is ~320cm(estimated diffusing frequency >100Hz). On the side walls of the front stage,there are another two small "flat" MLS diffusors started from the stall floor up to 3,0m height(depth is 12cm). Since the approximate position for the orchestra,they provide efficient lateral diffusion to the center of the stall level.

Owing to the staggered diffusors,the lateral sound energy has improved the previous strong frontal perception; also the long delayed repeated reflections are almost erased. Many smaller reflection picks are presented on the impulse response,the sound field becomes more homogeneous. **Figure 5** illustrates two impulse responses measured before and after the modifications of 1994 on the same position in Salle Pleyel.

2.3 Diagnosis and solutions for eliminate the echo on stage

To identify the sources of the audible echo percieved at the rear part of the stage is a delicate task in Salle Pleyel. Through the full scale mirror/laser beam test on the rear walls of the stall and 1st balcony,the reflections are fallen down locally. No "echo" should return to the stage,since these walls are already tilted 45°~50° towards the stage. The rear wall of 2nd balcony is vertical,but it is in plywood covered by a thick carpet,normally,the middle frequency echo should be attenuated. In 1994,the flat tier fronts of the balconies have been covered by the plywood in form of wedge(hypotenuse 135cm, apex 45cm),these convex tier fronts could not creat the echo. During the execution,we found a 2,0m height "invisible" plaster wall above the 2nd balcony,it may produce the echo. Then,a SONEX foam(5cm) has been glued on this wall,but the echo is still audible in the area of percussionist. Even after the installation of MLS diffusors on the ceiling and side walls,we have tried to change the tilted angle of the stage ceiling,but all of these efforts did not get a clear answer either. So,the echo problem has to be resolved in 2nd phase of 1995.

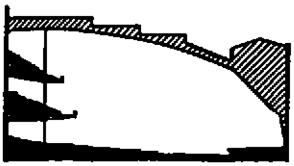
3.CONCLUSION

Even though the musical critics and the musicians had given the positive subjective reactions for the modifications of 1994,the acoustic problems have not been totally resolved.

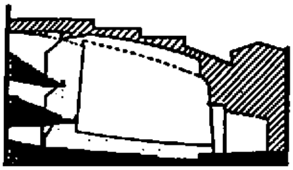
The maximum height of the stage ceiling is still too low. One interesting experience for the compensation is done by Russian National orchestra,they play the symphony in Salle Pleyel without raisers on stage. The bigger distance between the instruments(brass,percussion) and the stage ceiling,the better spaciousness and richness could be achieved. We believe that : higher stage ceiling,less aggressive sound.

After the modifications in 1994,the RT60(500Hz) of the empty hall is only 2,06 sec.(with the new uphostered seats) and the RT60 with 1800 persons is 1,8sec.. The estimated full occupied RT60 will be droped to 1,6 sec. as before. Regarding the volume of ~18000m3 of Salle Pleyel(including the space above the wood strips) and the capacity of 2386 seats,if we will lengthen the RT60,it may consider that : cover the wood strips ceiling totally by the hard panels. At the expense of losing ~10% of the upper volume(not contributive),the RT60 could be longer and the reflected string sound could be better. Moreover,the profil of the covered ceiling does not follow the parabolic line,so the sound diffusion will be further improved in Salle Pleyel.

ACOUSTIC PROBLEMS OF SALLE PLEYEL(PARIS) AND THE MODIFICATIONS IN 1994

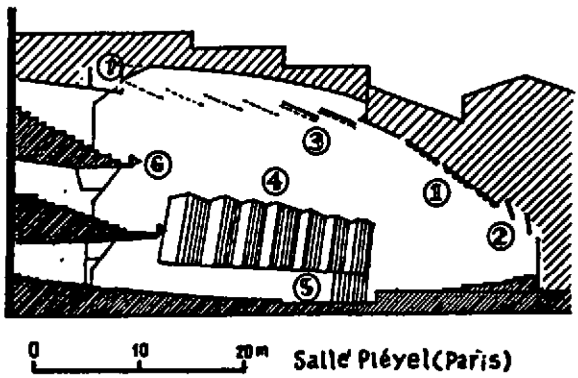


1927 Original(3000 seats)



1961 More absorption,low stage ceiling

1981 Less absorption,lower stage ceiling(2386 seats)



Modifications in 1994

1:Three MLS diffusive ceiling panels
2:Two flat panels tilted vertically
3:Two wood strips fause ceiling are covered by flat Alucobond panels
4:Staggered diffusors(l:16m/h:5m) tilted 12° inwards
5.Flat MLS diffusors
6.Convex tier fronts(apex:45cm)
7:Absorbing material on the wall

Figure 1.Historical evolution of Salle Pleyel and the modifications in 1994

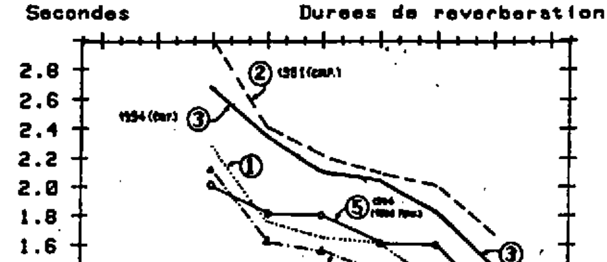


Figure 2.Reverberation Time measured in diffe- period for Salle Pleyel

1,2,3 are RT60(empty) meaured by Radio France, CSTB/XU and XU(1994)

4 is full occupied RT60 measured by CSTB/XU

5 is RT60 with 1800 per- sons,measured by XU(94)

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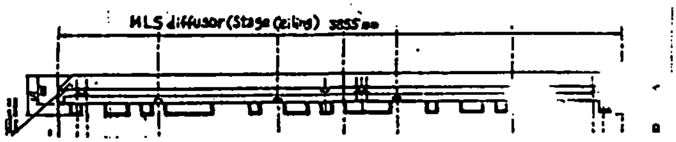

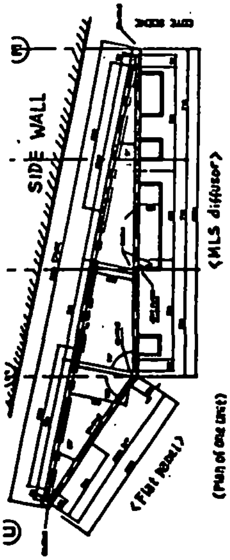

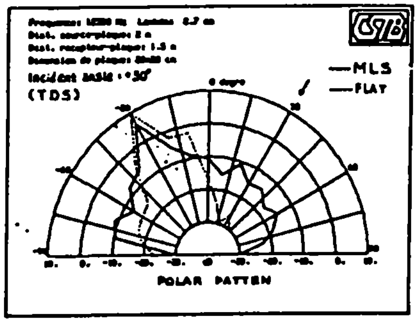

Figure 3.Typical polar patten of a MLS diffusor.The diffusion is measured on 1/20th model and compared with flat panel

Fifure4.(Top)MLS ceiling panel(stage) (Left)MLS and geometrical diffusor(staggered form)

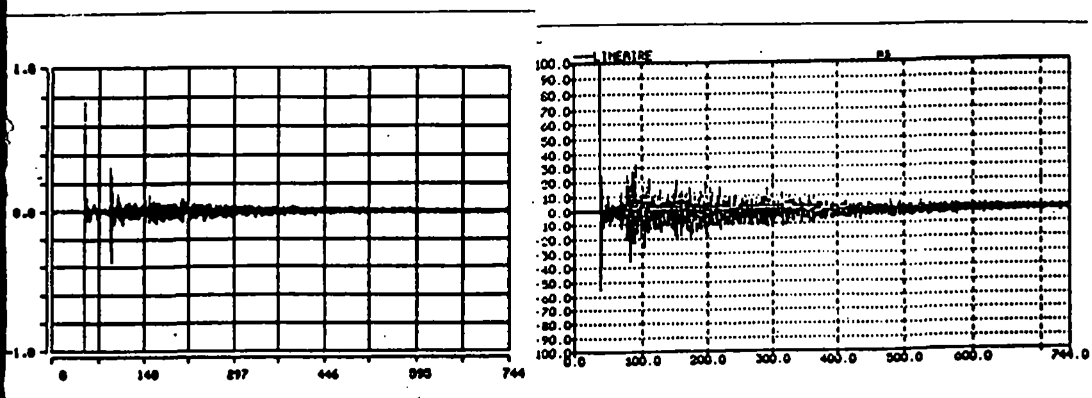

Figure 5.Two representative impulse responses measured before and after the modification at the same place in Salle Pleyel