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INVISIBLE ACOUSTICS IN THE RESTORATION OF THE GRAND THEATRE DE BORDEAUX

Albert Yaying Xu

XU-Acoustique,France

1.INTRODUCTION

The Grand Théâtre de Bordeaux(GTB) is an important historical monument[1] of France.It was built in 1780 and the architect was Victor Louis(1731-1792).This theatre was destinated for opera, but also for ballet and chamber music. The structural walls of the building are in stone,but the roof structure,the suspended balconies and most interior linings are in wood(Figure 1).

During the last two centuries,many restorations had been executed(1799, 1832,1853,1913).The original coloration within the main hall(white,blue,gold) was changed to dark red which was "la mode" of last century. The capacity of the hall was expanded from several hundred seats to 1200. The narrow orchestra pit of Louis(width of 2m,adapted for the small baroque orchestra),progressively,became very large comparing to the size of the hall.

In spite of its beauty and elegance,the audience's comfort was mediocre. There was no air conditioning system,the seats were so narrow,and the external noise could be heard due to the poor isolated doors. The sound inside the main hall was very dry(0,7 sec at 500Hz,occupied),the balance between the singer and the orchestra was inadequate,even though some of the public was so proud of its architecture,and occasionally,also of its acoustics.

The initial program of the restoration on 1990 didn't ask for any improvement,but only the conservation,of the interior acoustics of the theatre.Fortunately,since the 19th century's interior decoration has been completly renewed(back to Louis's decoration),so we've had the chance of convincing the authorities that improving the acoustics in this historical theatre could be "invisible" and still be audible.

The heavy tasks of the noise and vibration control are evident due to the installation of the powerful air conditioning systems located at the back of the stage and directly under the theatre. The new stage mechanical equipments and the "invisible" fire detection sensors(air aspiration) create many noise problems. But these problems are not part of our subject in this article,we would discuss in more details the topic of "invisible" room acoustics in the process of restoration.

2.ROOM ACOUSTIC DEFECTS OF THE THEATER

2.1.Volume of the hall and interior materials

The volume of the hall is 5227m3 and the full capacity is 1200 seats,the volumetric ratio is 4,3m3/seat. The compact space is benecifial for the propagation of the direct sound and the visual distance(19~20m). But inside the hall,there are crowded uphostered seats and velours curtains around the balconies,the red felted cloth glued on the walls,and the stage opening is absorbent as usual. The measured revebreration time(RT60) of the empty hall and the occupied hall are shown in Figure 2 (lower curves).

2.2.Shape of the hall and the Early reflections

The theatre is in quasi-italian style,it has three rows of opened balconies with french loges(i.e.,the separation wall stops at shoulder's height),and one gallery at the highest level,namely Paradis. This morphology also constitutes the significant acoustic variation among the seats at different levels.As usual,the sound is always better at higher levels than at the stalls(parterre) level. The echograms measured in four different seats(Figure 3 a~d) show the various behaviours of the early reflections. The main ceiling gives intensive reflections to the upper balconies(a and b),and the concave part of the ceiling focalize the reflections towards the Loge Municipale(1st balcony,c)with a time delay around 40ms.

On the lower part of the proscenium walls,there are two holes (openings of the box,1,44m2 for each) located on the important part of the reflecting path from the singer to the stalls. To verify the energy leak due to these openings,a comparative test has been done by means of a covering panel.Figure 4(a,b) shows two impulse responses measured at the center of the stalls. The lower curve illustrates the appearance of the enhenced early reflections(13ms delay),when one of the two openings was shielded by a wooden panel.

In fact,the worse place of the theatre is to be found near the central part of the stalls,in spite of the lack of early reflections,where the hihg frequency orchestral sound(i.e.,the 1st violins) is shielded by the pit's balustrade(in plywood) and the people in front.

2.3.Configuration of the orchestra pit

The original orchestra pit of Louis was very small which was probably adapted for the repertoire of his period. But,the later expansions of the orchestra pit create a sound masking problem for the singer. If we compare the ratio of hall/pit with other european operas(Figure 5),the orchestra pit in Bordeaux seems over dominant. The following table also shows some comparative data used in the analyse of Bordeaux's orchestra pit. (Table 1)

Theatre ref.(2)	volume/capacity (m3/seats)	pit's surface (m2 on Floor)	opening(O) surface,m2	ratio of O/F(%)
G.T. de Bordeaux	5227/1200	69	47,2	68,3%
Covent Garden	12240/2180	˜62	˜62	˜100%
Opéra de Paris	9960/2131	78	˜78	˜100%
Staatsoper of Vienna	10660/1658	107	˜107	˜100%
La Scala of Milano	11245/2289	125,4	111,5	89%
Festspiel-haus Bayreuth	10300/1800	138	34,5	25%

The sound masking effect is mainly produced by the powerful brass and percussion sections.These instruments are usually located at the rear part(against the wall) and under the overhang. Theorically,when a point sound source closed to the rigid reflectors,its sound can be enhenced up to 3˜4dB (relative to the free field condition). Therefore,the strong instruments are more "amplified" than the string section or the singer.Hanging some porous materials(e.g. velours curtain) on the rear wall of pit doesn't help the balancing. Then it is so difficult for the percussionist to play "lighter" in order to maintain a weakened sound with the correct timbre.The need to improve the orchestra pit was finally justified.

3.ACOUSTIC TREATMENTS IN THE RESTORATION

3.1.How to lengthen the reverberation time of the hall

In order to reduce the excessive absorption within the hall,a very special cooperation with the architect has been achieved.

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The final changes of the finishing materials of the hall are the following:

a)Most of the wall surfaces(~400m2) are covered by a painted varnished cloth(acrylique).It is glued on the plywood(5mm) and tightly screwed to the studs of the masonry wall.

b)The bottom part of the balconies are covered by a painted polyester cloth which is glued on the flat aluminium sheet (3mm).The aluminium base has been recommanded by the decorators and the acoustician(for the reflecting purpose).

c)The new designed seats are less absorbent than the original ones.The samples are measured in the acoustical Lab. of the HESCO Co.(Swiss). The absorption coefficients of the seats with audience(per m2) are: 0,64(125Hz) / 0,65(250Hz), 0,78(500Hz) / 0,81(1KHz) / 0,90(2KHz) / 0,79(4KHz).

d)The new wooden floor and the entrance doors are more smooth and reflecting than before.

Finally,the reverberation times of the restored hall have been measured when the hall was occupied and empty,they are :

(Table 2)

Hall condition (RT60 in Sec.)	Frequency band(1/1 Octave) Hz 125	250	500	1000	2000	4000
Occupied	0,8	1,0	1,1	1,1	1,0	0,9
Empty	1,14	1,27	1,23	1,2	1,19	1,16

3.2.Control of the Early reflections

In the restoration of this monument(GTB),there is no reason to change the geometry of the hall. Only one treatment has been realized for acoustics,that is the movable glass(6mm thick) which can close two box's openings on the proscenium walls in favour of the early lateral reflections(Figure 4 of 2.2.).The unpleasant optical reflection from the glass is limited by a special anti-reflex film. The voice of the singer is enhenced by these "invisible" reflectors.

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3.3.How to modify the orchestra pit for better sound balance

According to the analysis in 2.3.,the concrete changes are :

a)To move the rear wall of orchestra pit 1,4m towards the stage end.The expansion of the floor surface is not aimed to put a bigger orchestra,it is aimed to keep a larger distance between the "loud" instruments and the adjacent reflectors.

b)To install the perforated plywood(rate 7%) with 8cm air space(including 5cm rockwool) on the rear wall;the absorption pick is around 250~500Hz.On the bottom surface of the overhang,a 20mm acoustic foam is glued(reason of height).

c)The ratio between the opening area and the floor area is 60%(68,3% before),the string and woodwind sections are located there;under the covered part(40%),the percussion and brass sections use only 1/2 surface of it.

d)For a better sound radiation of the first violin's group, one half of the balustrade is covered by a tissue which is transparent acoustically and it only shields the vision of the lights in the pit. The other part of balustrade is covered by the plywood.There is a simple sound system which send back the orchestral sound towards the stage(in case of need).

The acoustic performance of this new orchestra pit is measured in a special way : fixing the receptor(mic.) at the middle of the stalls,only moving the sound source(omni-directional) along the central axe on the stage and inside the orchestra pit. The source signal is the white noise and the stability of sound power output is well checked.Figure 6. illustrates the sound level variation related to the source positions. The reference point(0dB) is defined at the stage curtain line,the six curves of different frequency band presents a general picture of the level variation. According to this picture,the conductor or the orchestra managers could localize their instruments in the orchestra pit more correctly and easily.

4.CONCLUSION

The above acoustic treatments are quite effective under the limitation of "invisibility" in a historical monument.It seems that the following problems have been partially resolved :

-The reverberation time has been lengthened in a wide frequency band.The sound has more fullness than before, but the Index of speech Intelligibility is still good. The values of STI measured in the empty hall are : 0,58 at the central stalls,and 0,68~0,7 at other places.

-The sound balance between singer and orchestra have been improved by two aspects : the enhencement of the singer's early reflection and the attenuation of the "overloud" orchestra sound.

-The sound of the first violin section is more brilliant than before(at the stalls area). The musicians are very pleasant to play in the new orchestra pit since the sound is heard much more clear and natural than before.

Nevertheless,the original volume of the hall has not changed. The Grand Théâtre de Bordeaux is still not suitable for the repertoire of Wagner,Verdi or other large scale performance. Its "speciality" is the Mozart,Bellini,Rossini,Massenet and the comic operas.

4.ACKNOWLEDGEMENT

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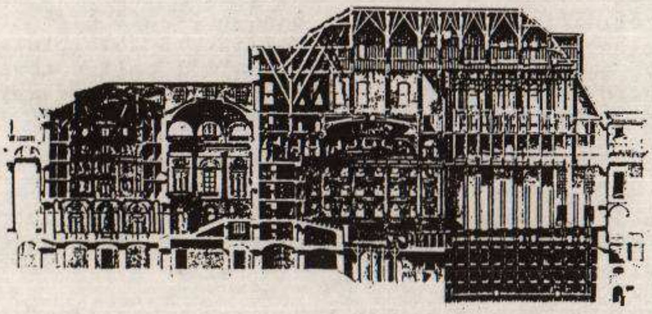
5.REFERENCES

(1)Victor Louis et le Théâtre,Editions du CNRS,Bordeaux,1982
(2)Beranek,Leo L.,Music,Acoustics & Architecture,1962



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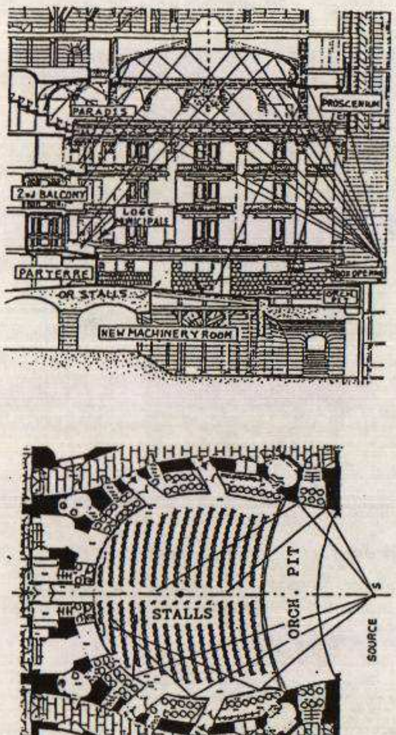

FIGURE 1. PLAN AND SECTION OF THE GRAND THEATRE DE BORDEAUX(FRANCE) STRUCTURAL WALLS:STONE / BALCONIES, ROOF & MOST INTERIOR LINING:WOOD

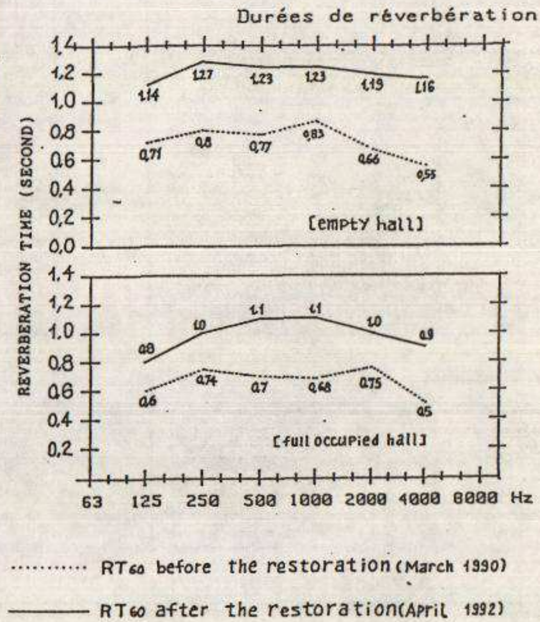

FIGURE 2. MEASURED REVERBERATION TIME BEFORE AND AFTER THE RESTORATION OF THE GRAND THEATRE DE BORDEAUX : RT60 OF EMPTY HALL(ABOVE) AND RT60 OF OCCUPIED HALL(BELOW)

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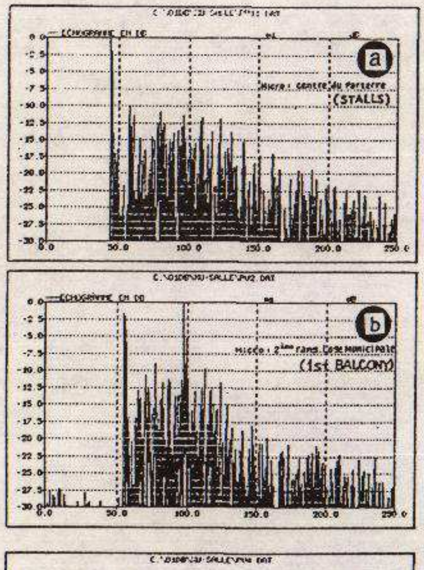

FIGURE 3. ECHOGRAMS MEASURED AT 4 DIFFERENT LEVELS IN THE THEATRE

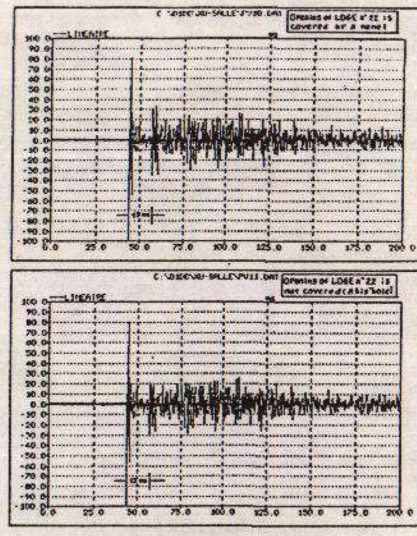

FIGURE 4. COMPARISON BETWEEN TWO IMPULSE RESPONSES OF SAME SEAT: LOGE OPENING CLOSED BY PANEL(ABOVE) AND LOGE OPENING NOT CLOSED(BELOW)

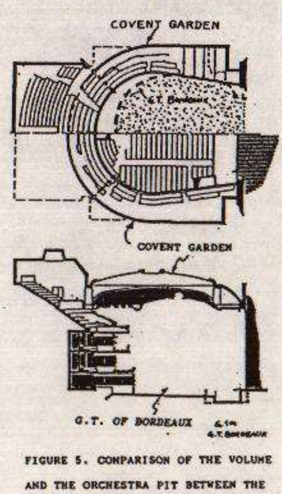

FIGURE 5. COMPARISON OF THE VOLUME AND THE ORCHESTRA PIT BETWEEN THE COVENT GARDEN AND G.T. OF BORDEAUX

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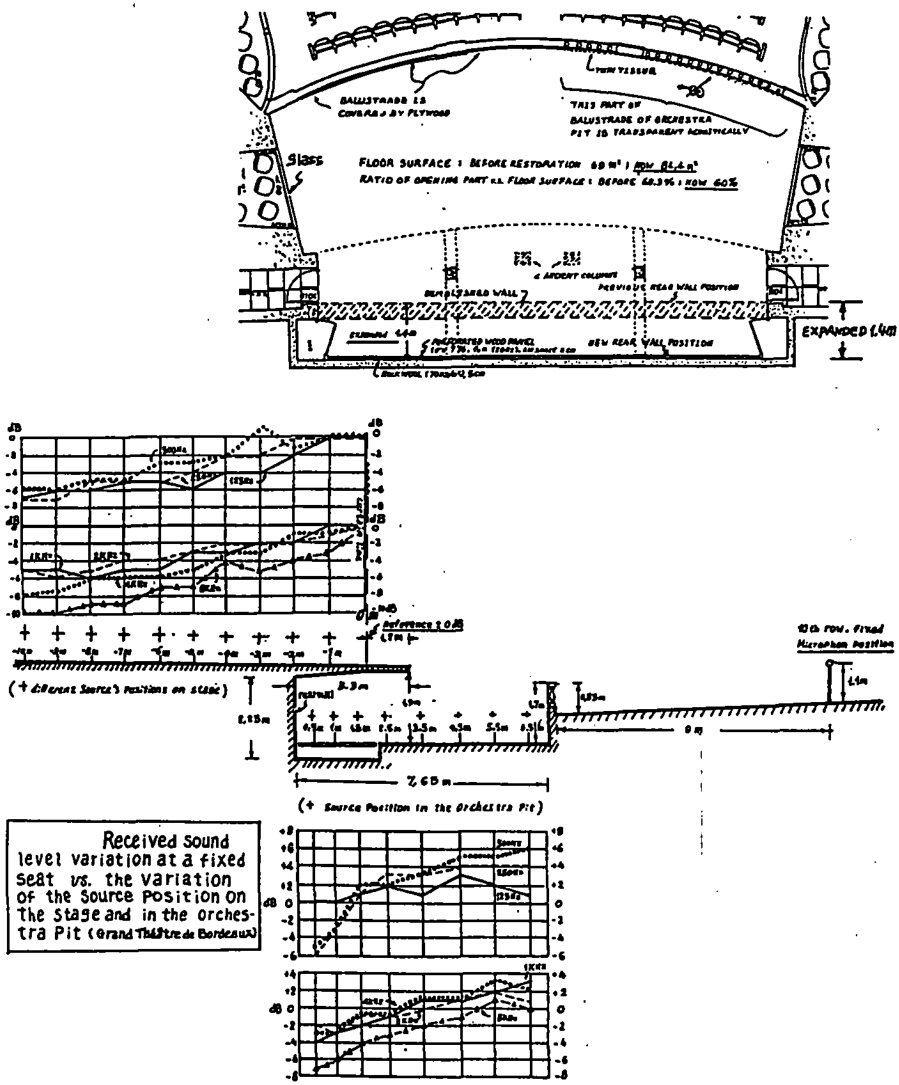

FIGURE 6. THE CONFIGURATION OF THE NEW ORCHESTRA PIT OF G.T.B. AND THE SOUND LEVEL VARIATION DEPENDING ON THE SOURCE POSITION