An Evaluation of Acoustic Performance in the Seoul Art Center Play House

예술의 전당 연극극장의 음향성능평가

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ABSTRACT

This study is an evalution of acoustic performance in Play House and aims to propose a rational design program through the checking of plan and acoustic evaluation in the Play House which is in the middle of accomplishment. The results will be used in the final stage of construction.

요 약

이 연구는 예술의 전당 연극극장의 실내 음향설계 평가에 관한 것으로, 실제 건물이 완성되어가는 중간단계에서 설계도면 검토와 현장에서의 음향실험을 통하여 합리적인 설계방안을 제시하고 그 결과를 최종 시공 과정에 적용하고자 한 것이다.

Ⅰ. Introduction

For an efficient acoustic design, Examination and pre-evalution about general building acoustics should be preceded from the early stage of building design. The room size, volume, space ratio between stage and seat, selection of interior finishing materials should be reflected in the acoustic examination. Finally, the results will be used in the last stage of acoustic evaluation after construction.

This study is an evaluation of acoustic performance in Play House and aims to propose a rational design program through the checking of plan and acoustic evaluation in the Play House which is in the middle of accomplishment. The results will be used in the final stage of construction.

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Ⅱ. Acoustic Performance Evaluation

2-1. Evaluation Outline

The Play House is a stage for a wide variety of drama performances. The auditiorium consists of one main stalls level and one balcony. The both sides of balcony are connected with a slope to the stage level to achive an all-embracing relationship with the stage. This arrangement will also enable actors to expand their acting area into audience seats on the stall and on the balcony cultivating more close contact between actors and audiences.

Measurement of Play House is shown in Table 1. The plan and section of Play House are shown in Figure1 ~ Figure 3.

Table 1. Measurement

Seat capacity(N)	Main stall : 498 Seat Ist Balcony : 195 Seat Orchestra Pit : 42 Seat
	Total : 735 Seat
Volume(V)	Auditorium(Va) : 4,502.46 M^3 Main Stage : 10,527.60 M^3 Lateral Stage : 2,250.0 M^3 Rear Stage : 3,038.0 M^3
	Total : 15,815.6 M^3
Surface Area(S)	2,100 M^2
Va / N	6.13 M^3/seat
Max.size of Hall	L : 20.0M, W : 26.4M, H : 13.3M
Size of Stage	Main－L : 24.78M,W : 15.0M, H : 22.1M Later－L : 15.0M, W : 15.0M, H : 10.0M Rear L : 18.78M,W : 16.18M, H : 10.0M
Orchestra Pit	W : 14.5 M, H : 5.1 M
Procenium	W : 12.0 M, H : 7.5 M
Floor Area(F)	Main Stall : 392.47 M^2 Ist Balcony : 187.8 M^2
	Total : 580.27 M^2
Stage Area	Main Stage : 392.47 M^2 Side Stage : 225.0 M^2 Rear Stage : 303.8 M^2 Orchestra Pit : 37.61 M^2
	Total : 938.11 M^2
Seat size	0.50 M × 1.0 M － 0.50 M^2

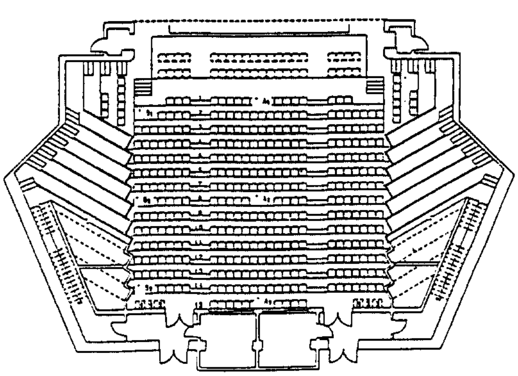

Figure 1. The main floor plan and measuring point

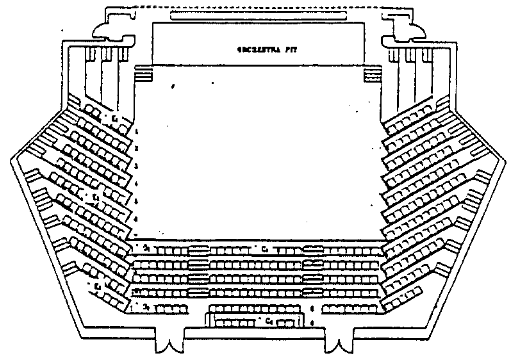

Figure 2. The 1st balcony floor plan and measuring point

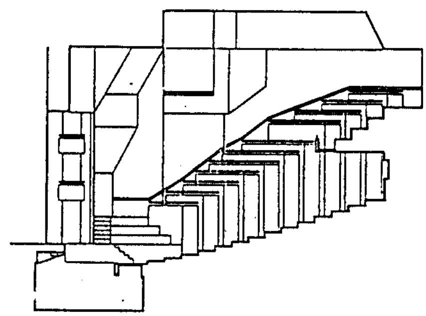

Figure 3. The section of Play House

2-2. Evaluation contents and Methods

As the room shape was symmetry, The measuring point of each audience seat was selected to be distributed evenly at all seats like Figure 1 ~ Figure 2. That was established after consideration of seat distance and room shape Sound source was setted on the front side of stage. The evaluation method of acoustic performance followed the standard of ISO and ASTM.

The test was carried out at 1992. 5. 31.

The equipments used in the test are as follows ;

- Real-time Frequency Analyzer Type 2133
- Sound Power Source Type 4205
- Microphone Preamplifier Type 2619
- Condensor Microphone Type 4165
- Sound Source Type 4224

B & K

Sound source used in test is pink noise and controlled as 1 /1 octave band.

Ⅲ. Results and Analyses

3-1. Sound Pressure Level and Ray-Digram Analyses

The measuring points classified by position were divided into main stall seats and balcony seats. The test results of sound pressure levels are shown in Table 2.

While the sound source power level on the stage was 110dB, the mean sound pressure level on seats was 93dB. So the difference of 17dB is shown.

Table 2. Sound pressure level distribution at each seat (source 1)

Freg. (Hz)		63	125	250	500	1000	2000	4000	8000	A.P dBA	Lin.
MAIN HALL	S.L	89	98	94	104	103	106	101	84	110	110
	A1	77	88	88	90	90	87	80	66	93	95
	A2	76	87	85	89	89	76	79	64	92	94
	A3	75	87	80	86	84	84	75	60	89	92
	$\overline{A}$	76	88	85	88	88	85	78	63	92	94
	B1	73	85	85	88	86	83	77	62	90	93
	B2	75	85	83	88	87	86	78	63	92	93
	B3	76	81	79	86	85	83	75	59	89	91
	$\overline{B}$	75	84	82	87	86	84	77	62	90	92
	$\overline{AB}$	75	86	83	88	87	85	77	63	91	93
BALCONY	C1	71	82	84	87	88	89	81	64	93	94
	C2	67	85	82	86	86	87	80	63	92	93
	$\overline{C}$	69	83	83	87	87	88	81	64	92	94
	E1	74	82	85	88	87	84	77	61	91	93
	E2	67	81	82	87	86	83	76	61	90	92
	E3	65	79	84	86	85	84	76	60	90	91
	$\overline{D}$	68	81	83	87	86	84	77	61	90	92
	$\overline{CDE}$	69	83	82	87	86	85	78	62	91	92
MEAN		72	84	83	87	86	85	77	62	91	93

Moreover, the difference of sound pressure level between the average of the whole seats and each seat was ±1dB. It showed very even distribution of sound pressure level. Mean sound pressure level difference between the 1st row and the last row seat showed very small difference of 2~3dB at main stall seat and 1~2dB at balcony seat.

Table 3. Sound pressure level attenuation value at each seat (based on sound source power level)

Frequency (Hz)		125	500	2000	A.P. (dBA)	A.P. (Lin.)
SOURCE LEVEL		98	104	106	110	110
MAIN HALL	A1	-10	-14	-19	-17	-15
	A2	-11	-15	-21	-18	-16
	A3	-11	-17	-23	-21	-18
BALCONY	C1	-16	-16	-18	-17	-16
	C2	-14	-18	-19	-19	-17
	E1	-16	-16	-22	-19	-18
	E2	-17	-16	-23	-20	-19
	E3	-19	-18	-22	-21	-19

"-"value is attenuation value(dB) when the sound source power level was eatablished as standard(0)

The result of Ray-Digram analysis by checking of plan, ceiling reflection from the sound source on stage didn't reach at 9~11 row and 14~15row seat in main stall.

Side wall reflection reflect mainly to the upper part of audience seat. But the path difference between stage and the lst row seat was relatively short. So the distribution of sound pressure level is no problem(Figure 4, Figure 5).

The result of Ray-Digram about acoustic defects(Figure 6) shows that as the sound which was reflected at the front panel of side balcony traveled to stage, there is a possibility of producing an echo on the stage. So proper treatment is needed to the front panel covering some kinds of

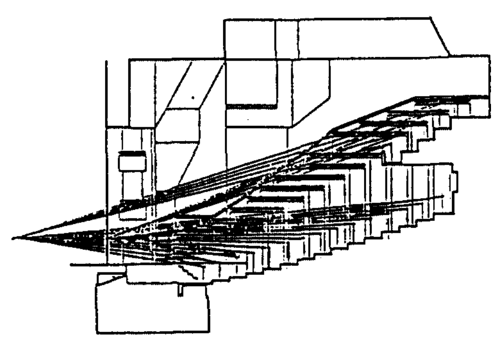

Figure 4. Direct sound ray analysis

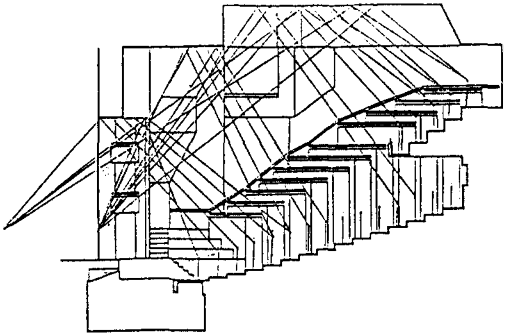

Figure 5. Reflection by ceiling surface

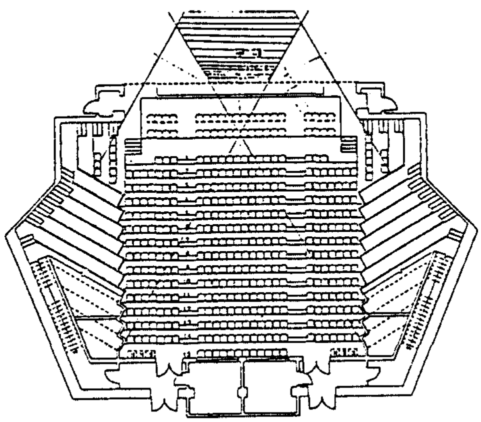

Figure 6. Checking of echo by reflection in the front panel of side balcony

absorption or diffusion material.

3-2. Reverberation Time and Interior Finishing Materials

When the reverberation time was tested, the surface of the Play House was exposed as concrete or wooden panel. Because interior finishing is not completed. So the main goal of the test was not to evaluate reverberation time but to analyze acoustic defect based on attenuation property.

The result of the test shows that mean reverberation time of the Play House was 3.75 second at 500Hz and the attenuation increased as frequency incresed. But at 125Hz, the reverberation time was relatively short(Table 4).

A result of calculation obtained by establishing the target reverberation time as 1.1second is

Table 4. Real test value of reverberation time at each seat

	63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
A1	3.42	3.77	3.95	3.76	3.46	2.54	2.03	1.23
A2	4.46	3.54	3.69	3.52	3.13	2.45	1.88	1.13
A3	4.40	3.88	4.01	3.61	3.24	2.41	1.87	1.25
B1	5.94	4.50	4.72	3.87	3.53	2.72	2.00	1.26
B2	5.02	3.87	4.23	3.77	3.24	2.46	1.86	1.21
B3	3.93	4.56	4.14	3.60	3.37	2.45	1.92	1.32
AB	4.53	4.02	4.12	3.69	3.33	2.51	1.93	1.23
C1	4.75	4.18	4.30	3.76	3.24	2.17	1.17	1.15
C2	4.63	3.57	4.04	3.78	3.05	2.17	1.62	1.10
D1	-	4.01	4.40	3.85	3.25	0.32	1.76	1.17
D2	-	3.37	4.30	3.71	3.29	2.25	1.71	1.09
E1	3.66	4.13	4.23	3.92	3.42	2.58	1.95	1.25
E2	-	4.41	3.84	3.82	3.24	2.60	1.94	1.24
E3	6.89	3.84	3.65	3.79	3.55	2.40	1.84	1.33
CDE	4.98	3.93	4.11	3.80	3.29	2.07	1.79	1.19
ABCDE	4.76	3.98	4.12	3.75	3.31	2.29	1.86	1.21

shown in Table 5. At this point, all parts, except the rear wall and floor which needs absorption treatment, were finished with wood.

Ⅳ. Conclusion

This paper presents a development plan for the acoustic property of Seoul Art Center Play House which is under construction. Initial construction drawings are studied and acoustic measurements are made at the construction site.

The results of pre-evaluation based on the drawings and acoustic measurements revealed no major defects. However, due to the limited examination and deviations in sound absorption rate of finishing materials, partial problems may arise after the construction and this some degree of modifications may be required.

Also, when the construction is finished, physical acoustic evaluation as well as subjective evaluation based on questionaire for acoustic experts, musical directors, instrumental players, and audience, may be required for proper re-

Table 5. Calculation of reverberation time

Freq.		Area (M²)	125Hz		250Hz		500Hz		1000Hz		2000Hz		4000Hz	
			a	'aS	a	aS	a	aS	a	aS	a	aS	a	aS
F1	A1-1	338	0.49	165.6	0.66	223.1	0.8	270.4	0.88	297.4	0.82	277.2	0.7	236.6
	A1-2	338	0.55	185.9	0.7	236.6	0.84	283.9	0.92	311	0.88	297.4	0.78	263.6
	A1-3	338	0.6	202.8	0.74	250.1	0.88	297.4	0.96	324.5	0.93	314.3	0.85	287.3
F2	R1	190	0.04	7.6	0.04	7.6	0.07	13.3	0.06	11.4	0.06	11.4	0.07	13.3
F3	R1	34.6	0.04	1.384	0.04	1.384	0.07	2.422	0.06	2.076	0.06	2.076	0.07	2.422
F4	A6	116.3	0.3	34.88	0.35	40.69	0.4	46.5	0.4	46.5	0.4	46.5	0.4	46.5
FW	R1	953.4	0.04	38.14	0.04	38.14	0.07	66.74	0.06	57.21	0.06	57.21	0.07	66.74
RW	A5C	105.2	0.3	31.56	0.84	88.38	0.88	92.58	0.71	74.7	0.58	61.02	0.59	62.07
C1	R1	534.2	0.04	21.37	0.04	21.37	0.07	37.39	0.06	32.05	0.06	32.05	0.07	37.39
AIR	A7	4500	–	–	–	–	–	–	0.003	13.5	0.007	31.5	0.02	90
SUM		2272	0.132	300.5	0.185	420.6	0.233	529.3	0.23	521.4	0.215	487.4	0.205	465
Up-occupied		Mean	2.261		1.567		1.21		1.231		1.392		1.401	
		$T_{500-1000}$											1.22	
Occupied (50%)		Mean	2.108		1.513		1.175		1.195		1.269		1.315	
		$T_{500-1000}$											1.19	
Occupied (100%)		Mean	1.994		1.462		1.142		1.161		1.222		1.246	
		$T_{500-1000}$											1.15	

(Note)

F1 Seat F2 Aisle
F3 Orchestra Pit F4 Procenium Opening
FW Side Wall RW Rear Wall
C1 Ceiling AIR Air Absorption

	Absorption Ratio 125Hz	250Hz	500Hz	1KHz	2KHz	4KHz
A1−1 Upholestered Seats(Unoccufied)	0.49	0.66	0.80	0.88	0.82	0.70
A1−2 Upholestered Seats(50% Occu.)	0.55	0.70	0.84	0.92	0.88	0.78
A1−3 Upholestered Seats(100% Occu.)	0.60	0.74	0.88	0.96	0.93	0.85
R1 Wooden Panel on Concrete	0.04	0.04	0.07	0.06	0.06	0.07
A6 Procenium Openings	0.03	0.35	0.40	0.40	0.40	0.40
A5C Aluminum board(Perforated)	0.03	0.84	0.88	0.71	0.58	0.59
A7 Air	–	–	–	0.003	0.007	0.02

adjustment.

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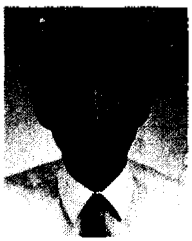

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