Acoustic Examinations of the Hanoi Concert Hall

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The Hanoi concert hall was constructed in 2014 and designed especially for classical music. Moreover, it was the first concert hall requiring highly technical architectural acoustics in Vietnam. At the time, we had the chance to support this project involving architectural acoustics from the drawing board stage in 2010 until the end of construction in 2014.

This paper shows how the acoustic needs of this concert hall were met, e.g. in terms of reducing traffic and indoor noise, adjusting reverberation time and electro-acoustics and so on. The acoustic examinations to meet these requirements were performed on a step-by-step basis throughout the drawing and construction period. Ultimately, this project was realized and the new concert hall now has first-rate architectural acoustics.

Keyword：Acoustical examination, concert hall, reverberation time, traffic noise, electro acoustic

1. The project outline

The first concert hall for classical music was built in Hanoi by the Vietnamese themselves in a project that started more than 15 years ago. Figure 1 shows the location of this concert hall, Table 1 its outline and Figures 2 and 3 show the interior and drawings respectively.

Table 2 shows the three main acoustic designs intended to meet the acoustic demands of this hall, reflecting the general perspective for architectural acoustics.

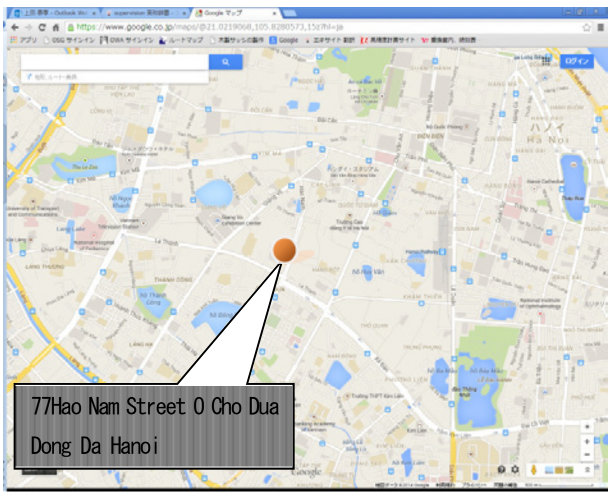

Figure 1　location of this concert hall

Table 1　Conditions of Hanoi concert hall

Item	Outline
Customer	Vietnam National Academy of Music (VNAM)
Architecture	Ministry of Education and Training Institute for Research and Design School
Contractor	Tekcast and Vinaremon company
Acoustical supervision	Hazama-Ando corporation & Yuko OGAWA
Performance purpose	Classic music
Reverberation Time (500Hz)	1.8±0.1sec (With audience and player)
Silence	Below 30dB
Seats	900 seats 100 players on the stage 120 corals
V/S	2.6 ≒ 16,724 m^3 / 6,500 m^3
Interior materials	Ceiling: GRG (mainly) Wall: wooden diffuser and stone Floor: foaling and seat

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Figure 2　Inner view

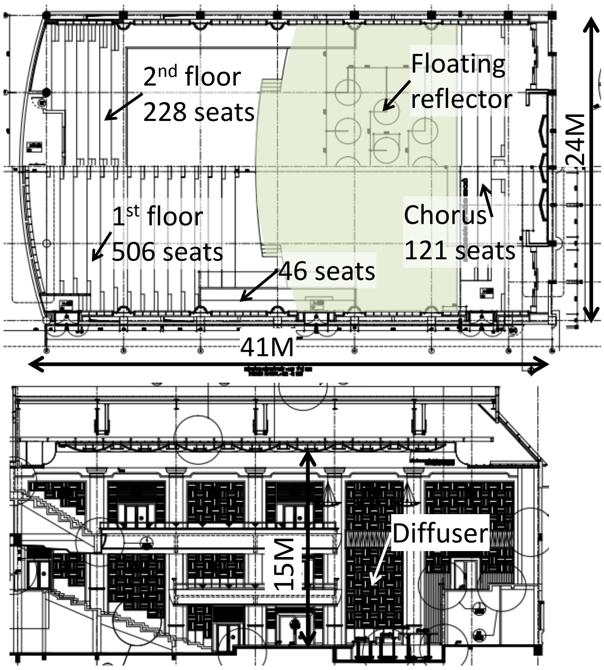


Figure 3　Plane and cross section

Table 2　Demands and acoustical examinations

Demand of acoustical design item	Outline of acoustical examination
Noise reduction design	How to reduce outdoor traffic noise and indoor equipment such as air handling unit, pomp and so on.
Architectural acoustic design for usage are built	Target RT is realized by adjusting inner material and its location. Computer simulation is done in order to prevent from sound problems such as flutter echo or long pass echo.
Sound system infrastructure design	The types of facilities (such as reflector, control room, speaker location and combination, public assist, recording system, announce and so on) are judged by a point of necessity.

2. Acoustic examinations

This section includes details of, some specific acoustic examinations.

2.1 Outdoor noise reduction

Traffic noise on the wayside tends to be very loud in Vietnam.

Conversely, "silence" is imperative for the concert hall and the outdoor sound level (see right photo) should be measured to allow the required degree of sound insulation for exterior and interior materials to be determined.

Figure 4 shows the traffic noise at the construction site recorded on March 15, 2011, 18:00 ～ 23:05.

The noise level peaked at around 90dB, mainly from bus horns and a minimum 60dB reduction would be required to keep the interior noise level under 30dB. We designed the sound insulation as shown in Table 3; mounting a double-layer door.

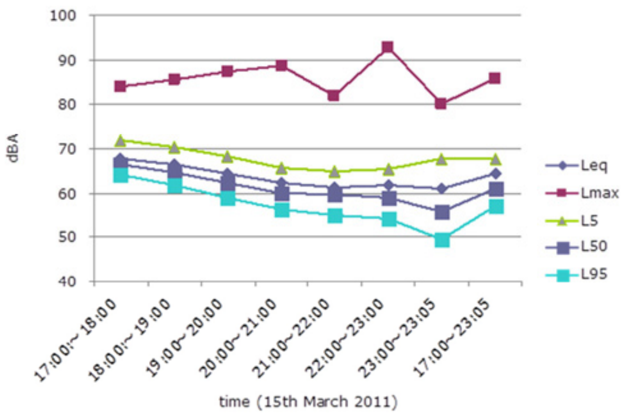


Figure 4　Traffic noise at the construction site

Table 3 Target of sound insulation

Position	Target
The sound insulation loss of outer material (windows and outer material)	> 30dB
The sound insulation loss of inner material (door and wall)	> 40dB

2.2 Indoor noise reduction (air-conditioning equipment)

Noise generated by indoor equipment also had to be examined, which mainly involved reducing the noise of the air-conditioning system. Figure 5 shows a sample and how this issue was repeatedly discussed. We used Internet meetings, met face to face, and visited Vietnam TV to understand how best to reduce noise.

Finally, one absorbent chamber was added to each supply-air duct between the machine room and interior (Figure 6). Based on these measurements, we assumed the noise from the air-conditioning system would be lower than 30dB at the hall floor level.

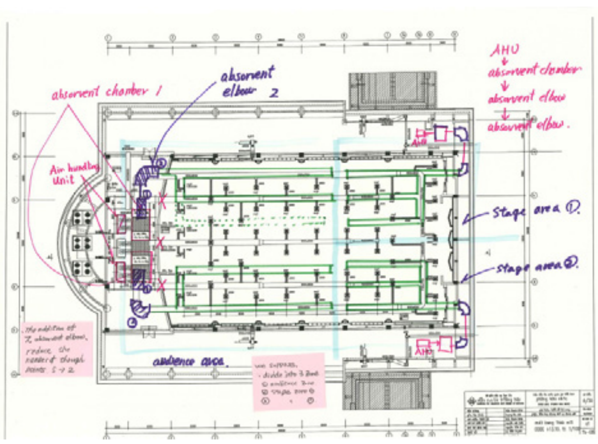


Figure 5 Discussion sheet with engenders of air-conditioning equipment

Figure 6 Location of the additional absorbent chamber (■) at each supply duct

2.3 Reverberation time (RT)

RT was calculated using an excel sheet (see next page). and Figure 7 shows the RT result with and without an audience, while Figure 8 shows the relationship between estimated and recommended RT respectively.

The predicted RT almost matched the value required by the customer.

Some adjustment area were set at ceiling. If RT after construction was deferent from our calculation, we could control RT value by managing adjustment area.

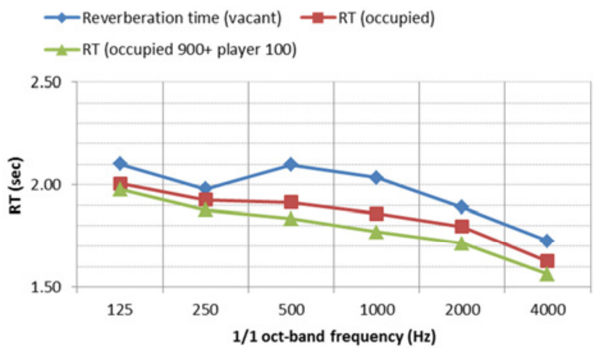


Figure 7 RT estimation at the drawing period

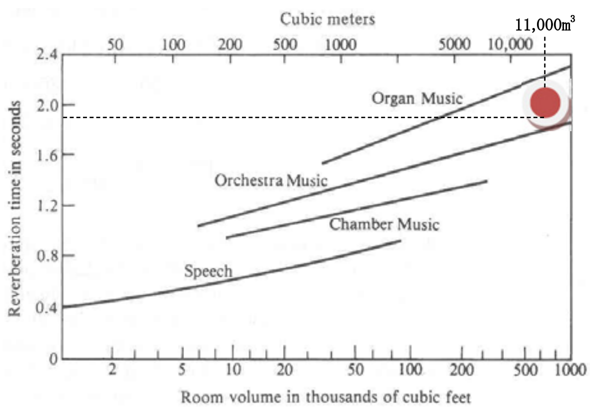


Figure 8 RT target and recommended RT1)

2.4 Computer simulation

(1) Outline of-the computer simulation

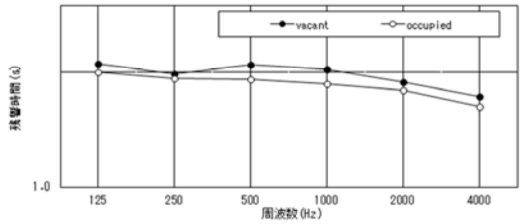
Acoustic problems such as flutteror long-pass echo have to be prevented in concert halls, hence a geometric simulation method (software: ODEON) was performed to reveal the fundamental acoustic conditions of the Hanoi concert hall.

Although the ceiling diffuser is actually round in shape, it is modeled on an acute triangle this time (with the diffuser depth of the same size). If the room shape

Reverberation time of Vietnam concert hall

【conditions】
surface : 4080.0
volume : 11000.0
V／S : 2.7
seats : 901
purpose : classic consert
target : 1.84

500Hzの残響時間
平均吸音率を
0.21 と仮定
RT = 1.8 s



※材料名称は下記にまとめて示す。

部位 location	材料名称 mateiral name	面積 surface	125 吸音率	125 吸音力	250 吸音率	250 吸音力	500 吸音率	500 吸音力	1000 吸音率	1000 吸音力	2000 吸音率	2000 吸音力	4000 吸音率	4000 吸音力	備考 (材料データ)		
舞台廻り	舞台床 floor	350.0	0.14	47.25	0.09	31.50	0.06	22.05	0.05	15.75	0.05	18.90	0.06	22.05	7010	ロンリューム(5)+合板(20)+AS大	0.90
Stage area	舞台後ろ壁 wall (back)	110.0	0.27	21.38	0.27	21.38	0.32	24.95	0.36	28.51	0.27	21.38	0.18	14.26	2270	拡散体 実測値	0.90
	舞台 前面 wall (front)	15.0	0.20	3.00	0.15	2.25	0.12	1.80	0.09	1.35	0.09	1.35	0.09	1.35	5541	舞台前部	1.00
合唱席廻り	合唱席 seats	121席	0.22	18.82	0.27	23.52	0.32	27.44	0.32	28.23	0.38	32.93	0.34	29.80	6041	コトブキ 空席時	0.90
chorus area	床部分 floor	117.0	0.14	15.80	0.09	10.53	0.06	7.37	0.05	5.27	0.05	6.32	0.06	7.37	7010	ロンリューム(5)+合板(20)+AS大	0.90
客席	1階 客席 seats on 1st floor	506席	0.22	78.69	0.27	98.37	0.32	114.76	0.32	118.04	0.38	137.71	0.34	124.60	6041	コトブキ 空席時	0.90
audience area	1階 客席 以外の床 floor	220.0	0.14	29.70	0.09	19.80	0.06	13.86	0.05	9.90	0.05	11.88	0.06	13.86	7010	ロンリューム(5)+合板(20)+AS大	0.90
	中間階 客席 seats on balcony	46席	0.22	7.15	0.27	8.94	0.32	10.43	0.32	10.73	0.38	12.52	0.34	11.33	6041	コトブキ 空席時	0.90
	2nd floor (mid)	40.0	0.01	0.40	0.01	0.40	0.02	0.80	0.02	0.80	0.02	0.80	0.03	1.20	5024	花こう岩 水みがき	1.00
天井	バルコニー下(中間階) balcony	7.0	0.10	0.70	0.11	0.77	0.07	0.49	0.06	0.42	0.06	0.42	0.06	0.42	2230	合板(15)+AS(180)	1.00
ceiling	バルコニー下(2階) 2nd floor	290.0	0.10	29.00	0.11	31.90	0.07	20.30	0.06	17.40	0.06	17.40	0.06	17.40	2230	合板(15)+AS(180)	1.00
	天井 下段 調整 舞台側 ceiling	194.0	0.10	19.40	0.11	21.34	0.07	13.58	0.06	11.64	0.06	11.64	0.06	11.64	2230	合板(15)+AS(180)	1.00
	天井 下段 調整 客席側	80.0	0.50	40.00	0.70	56.00	0.52	41.60	0.65	52.00	0.68	54.40	0.60	48.00	3046	あなあき板(5)6-15P(RW25-50K)開口率13%+AS(270)	1.00
	天井 立上り	252.0	0.10	25.20	0.11	27.72	0.07	17.64	0.06	15.12	0.06	15.12	0.06	15.12	2230	合板(15)+AS(180)	1.00
	天井 上段 平ら	115.0	0.10	11.50	0.11	12.65	0.07	8.05	0.06	6.90	0.06	6.90	0.06	6.90	2230	合板(15)+AS(180)	1.00
	天井(凸面)	500.0	0.10	50.00	0.11	55.00	0.07	35.00	0.06	30.00	0.06	30.00	0.06	30.00	2230	合板(15)+AS(180)	1.00
表面積(m²)		4080															
容積(m³)		11000														補正	
空席時吸音力				761.52		803.15		762.90		784.20		766.85		695.69	低	中(250~1000Hz)	高
平均吸音率			0.19		0.20		0.19		0.19		0.19		0.17		1.00	1.00	1.00
Reverberation time (vacant)			2.10		1.98		2.10		2.03		1.89		1.72				
着席時		901	0.05	32.44	0.03	19.46	0.1	64.87	0.1	64.87	0.06	38.92	0.08	51.90	6039	セイントオメールクラブ 着席時	1.00
満席時吸音力				793.96		822.61		827.77		849.07		805.77		747.59	低	中(250~1000Hz)	高
平均吸音率			0.19		0.20		0.20		0.21		0.20		0.18		1.00	1.00	1.00
RT (occupied)			2.01		1.93		1.91		1.86		1.80		1.63				
ステージ 100名 着席時		100.0	0.10	10.00	0.19	19.00	0.32	32.00	0.38	38.00	0.38	38.00	0.36	36.00	6007	成人（木製椅子、プラスチック椅子に座る）	1.00
満席時吸音力				803.96		841.61		859.77		887.07		843.77		783.59	低	中(250~1000Hz)	高
平均吸音率			0.20		0.21		0.21		0.22		0.21		0.19		1.00	1.00	1.00
RT (occupied 900+ player 100)			1.98		1.88		1.83		1.77		1.71		1.56				

is modeled in detail, the surface-area error tends to be considerable, which would lead to acoustic parameters (such as RT…) changing against the actual hall.

Figure 9 shows this simulation model, while Figure 10 shows the inner material location in the hall. Warm colors represent material with a high absorption coefficient, while cold colors refer to that with low absorption.

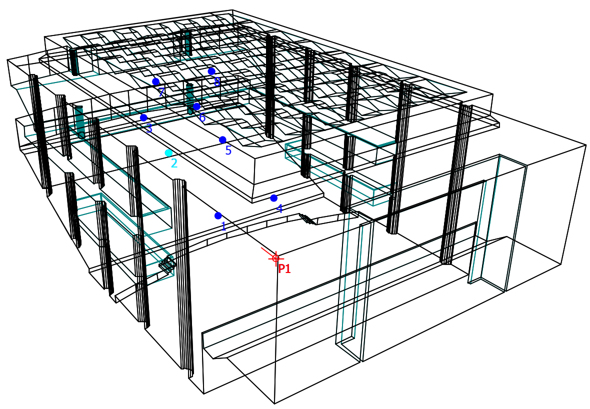


Figure 9　Geometrical simulation model (receiving point 1 – 8, P1 is signal source)

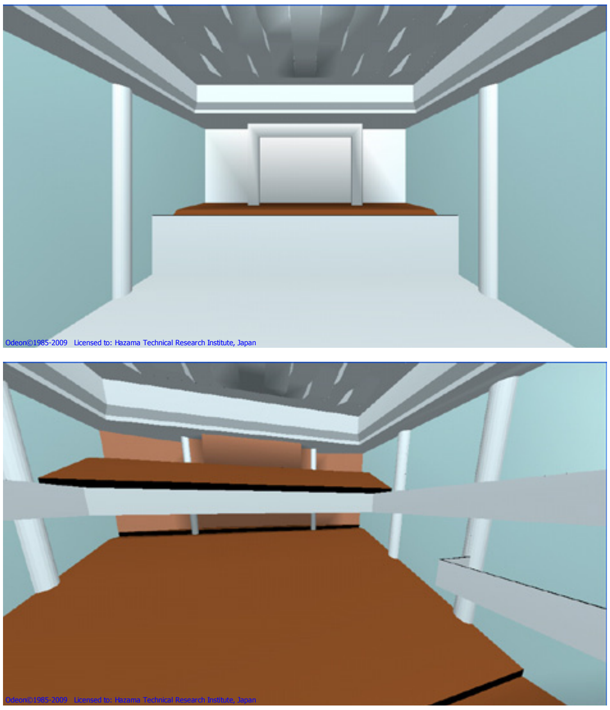


Figure 10 Inner material location in the hall

(2) Simulation results

Characteristic trends are initially indicated as follows. At receiving point 1, located at the front side in the hall, some reflected sounds emerge from each side wall. Since each side wall is covered by a diffuser, flutter echo would be diminished by them at a high frequency range.

Conversely, at receiving point 3 at the rear of the hall, the sound comes from the front and back wall. Diffusers are also installed on both front and rear walls, both of which also have diffusers installed.

These examinations revealed the following.

・ Diffusers on the ceiling and wall impact on the acoustics and must be made of hard material to be effective.
・ The absorption coefficient of diffusers should be checked. Because diffusing sound involves absorbing it, the diffuser would impact on the reverberation time.
・ The audience area under the balcony tends to be a shadow zone in acoustic terms. Using electro-acoustic equipment could help amplify SPL in this area (see figure 14).

2.5 Electro-acoustics

(1) Outline of electro-acoustics

This hall is mainly used for classical concerts. When classical music is performed, all electro-acoustic systems are suspended except for the recording systems. The

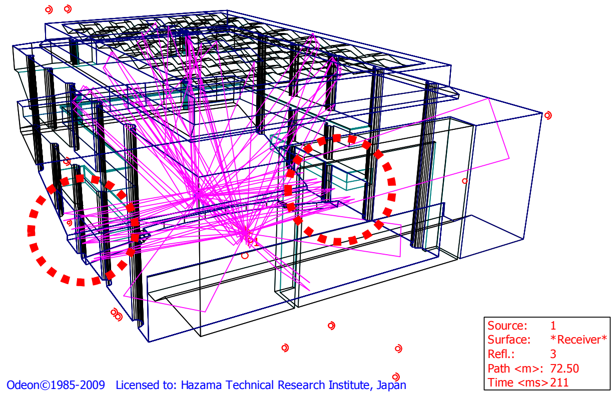


Figure 11 Sound simulation at P1

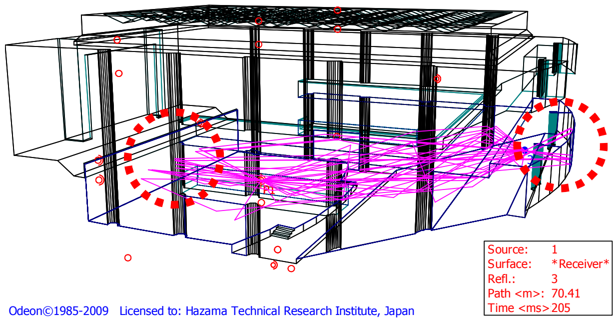


Figure 12 Sound simulation at P3

other main use of this hall is for lecture meetings. The stereo effect is not important in either case and heavy electro-acoustic systems e.g. designed for rock concerts would not fit a classical concert hall. Accordingly, a simple electro-acoustic system was proposed and future expansion functions configured, such as the connection box, the power outlet and the line route... After construction, the operator should take care of aspects in terms of safety and retaining the function, which means

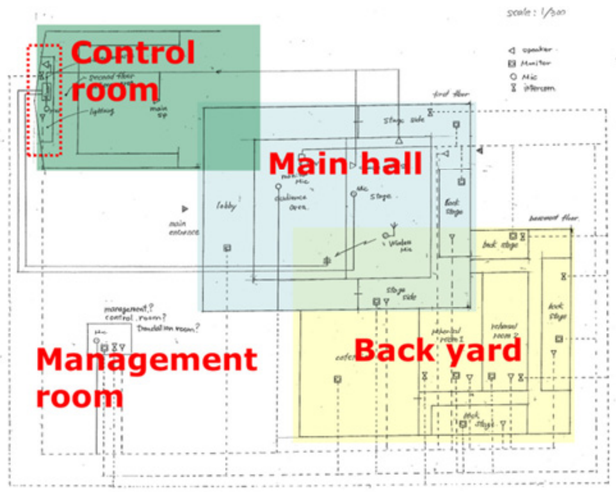


Figure 13 Rough sketch of electro acoustic system

we had to choose this equipment and these systems from perspectives such as ease of operation and maintenance.

Anyway, the electro-acoustic system must cover the control room, backyard area, public zone and management room as well as the main hall, meaning it has to take connections between these areas into consideration.

(2) Electro-acoustic examination

Figure 14 shows the SPL distribution from the main, wall and ceiling speakers. While the main speaker covers almost the entire audience area, the wall and ceiling speakers boost weaker areas which the main speaker cannot cover.

Similarly, the stage and chorus areas should also be covered by the speaker.

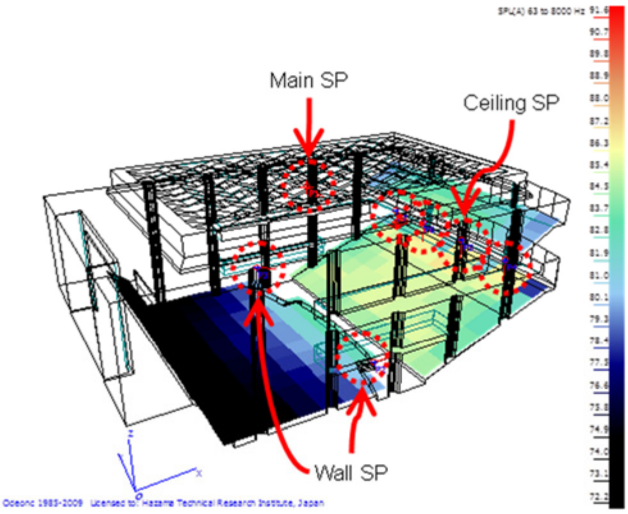


Figure 14 SPL distribution from speaker

2.6 Inspection during the construction period

(1) The construction process

The following pictures show the construction process at the front of the hall, where a hole for piping and ducting represents a weak point for sound insulation loss. After installing inner material, these gaps would be concealed and hard to modify. Accordingly, it is crucial to check various parameters at each stage to maintain acoustic quality.

When such inspection reveals any acoustic problem, adjustments should be designed in advance. At this time, preparations are made behind the balcony ceiling to adjust the RT area(see arrow in the right picture).

Without seat condition

After installing audience seat

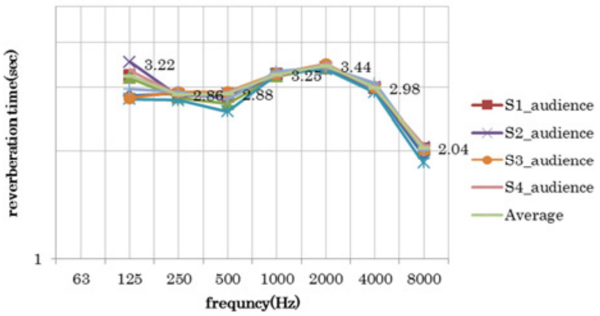


Figure 15 RT without seat

Surfaces: 4,000 ㎡, Volume: 10,100 ㎥

Hz	RT without seat	$\bar{\alpha}$ without seat	①	α of seat (90%)	②	① + ②	$\bar{\alpha}$ with seat	RT with seat
125	3.22	0.13	517	0.22	194	711	0.17	2.26
250	2.86	0.14	578	0.27	243	821	0.20	1.93
500	2.88	0.14	575	0.32	283	858	0.21	1.84
1000	3.25	0.13	513	0.32	291	804	0.20	1.98
2000	3.44	0.12	486	0.38	340	826	0.20	1.92
4000	2.98	0.14	555	0.34	307	863	0.21	1.83

$RT = \frac{.161 \times Volume}{-Surface \times \log_e(1-\alpha)}$, RT; Reverberation time, α ; Absorption coefficient (AC)

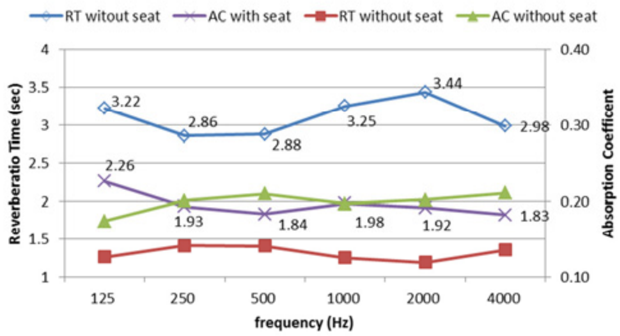


Figure 16 RT with seat is estimated

2.7 Acoustic conditions

(1) Without audience seats

Acoustic measurement without seats was performed to estimate the acoustic conditions with seats and if any problems emerged, proposed solutions had to be discussed before construction was completed. The following summarizes the measurement result.

When measuring RT without seats, RT with audience seats was estimated at about 1.84 sec with the premises empty. It was confirmed that the figure for RT with seats would be implemented on the plan.

Other acoustic indexes, which were also measured, are omitted due to lack of space.

(2) With audience seats

① Reverberation time (RT) with seats

The RT without an audience is about 2.0 sec and the absorption coefficient is 0.2, based on the room volume and surface area. The RT with the room fully occupied (900 persons) is also estimated at just below 1.8 sec (absorption coefficient: 0.21) based on the measured data. There is no current need ,to modify inner materials to adjust RT.

② Transmission loss of doors around the concert hall

Outer windows were not installed at the time, and gaps around doors remained, so the data should be treated as reference. After windows and doors are installed as we requested previously, the outdoor noise within the hall would be reduced to under 30dB.

③ Sound distribution from the main speaker at audience level

The distribution of the sound-pressure level from the SP system is within 6dB. The low frequency on the 1st floor is obvious due to the woofer speaker set beside the wall and some adjustments would be made.

④ Air-conditioning noise

When three air-conditioning machines were operated, the Noise Criteria was confirmed as NC-20, which represented good quality silence for music.

⑤ Lightning system noise

When the ceiling lights and spot light around the stage were on, we confirmed that we were not aware of any noise from them.

⑥ Audition of sample music measured in the anechoic room

We did not hear any acoustic problems after listening. The music was generated by a monopole speaker in the center of the stage.

⑦ Audition of real instruments (traditional and western music)

We did not hear any acoustic problems after listening in the audience and stage areas, with traditional and western music played. Although traditional drums were played in the center of the stage, no flutter echo in particular (or other acoustic problems) was heard at all.

We suppose that the position of solo (piano, violin…) and small installments (duets, trios and quartets…) should be carefully examined for each formation.

Hz	RT with seat	$\bar{\alpha}$ with seat	①	α of audience	②	① + ②	$\bar{\alpha}$ with audience	RT with audience
125	2.4	0.17	676	0.05	45.0	721	0.18	2.23 2.21※
250	2.1	0.19	762	0.05	45.0	807	0.20	1.97 1.95※
500	2.0	0.19	787	0.10	90.0	877	0.21	1.79 1.77※
1000	2.1	0.18	753	0.10	90.0	843	0.21	1.88 1.85※
2000	2.0	0.19	790	0.08	72.0	862	0.21	1.83 1.80※
4000	1.7	0.23	938	0.05	45.0	983	0.24	1.57 1.56※

※ audience 900 + player 120 = 1020

Figure 13　Audition of real instruments (upper: western style, lower: traditional style)

3. Conclusions

Thanks to continuous effort made over more than 15 years to build this concert hall, the acoustic quality is almost perfect, although there is room to improve the process of acoustic examination. Despite the lack of acoustic data for construction materials in Vietnam, which hampers efforts to estimate acoustic conditions in advance, this situation would be resolved in the near future.

While we discuss from the engineering perspective, the Vietnam side accustomed themselves to think and examine aspects in terms of acoustic quality control through this project.

Finally, we got the appreciation of the famous player, Dang Thai Son, concerning the “HIBIKI” of this concert hall.

We hope that the second and third Dang Thai Son would appear in future when this concert hall is complete.

4. Acknowledgments

We are deeply grateful to Deputy Rector Le Van Toan, Nguyen Thi Hai Van, Architect President Dr. Tran Thanh Binh, Dr. Nguyen Anh Tuan for their cooperation in this project.

We would also like to express our gratitude to Mrs. Dam and Mr. Hoang for their translation and advice on Vietnamese matters.

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ハノイ音楽ホールの音響検討

上田泰孝，小川有子

ハノイ音楽ホールが，2014年に完成した。本ホールは，ベトナム国内で始めての音楽専用ホールであり，高い建築音響技術が必要であった。我々は2010年から2014年まで本ホールの建設プロジェクトに係わることができた。

本報告書は，この音楽ホール建設時に求められた音響性能を実現するプロセスを示している。外部からくる交通騒音や内部の空調騒音の低減，残響時間の調整，電気音響システムの導入など建築音響項目は多岐に渡り検討が必要であった。このような項目について設計段階から施工段階までベトナム側スタッフと一つずつ検討を重ね具体化していった。

最終的に当初の目標音響性能を実現することができ，民族音楽から西洋音楽までの音楽に対応できることを確認した。本ホールの建設により，ベトナム国内のみならず世界各国の音楽を楽しむ為の基盤が出来た。

今後，文化的な発信場所となっていくことを祈念する。

キーワード：音響検討，コンサートホール，残響時間，交通騒音，電気音響