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Acoustical characteristics of preserved wooden style Kabuki theaters in Japan

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Summary

The acoustical characteristics of traditional wooden style Kabuki theaters were investigated, representing the most important, genuinely Japanese performance venue for theater and music during the late 19th and early 20th century. Five halls were selected as a representative sample of the extant wooden style Kabuki theaters, including the Kompira Ōshibai, built in 1835, as the oldest existing example. Standard room acoustical parameters according to ISO 3382 were derived from measured impulse responses, documenting the particular acoustical characteristics of this building type, as well as the range of variance. In addition, computer models were created in order to reconstruct the acoustical conditions during performance for the occupied condition. With reverberation times between 0.5 and 1.0 s and values for the definition $D_{50} > 0.7$ in the occupied condition, these venues are clearly optimized for high clarity and speech intelligibility, notwithstanding the important musical parts of the plays performed.

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1. Introduction

The beginnings of Kabuki as a classical Japanese form of dance-drama date back to the beginning of the Edo era at the beginning of the 17th century. It was originally played by female performers until the Shogunate prohibited all women on stage in 1629. The so called yarō-kabuki with both male and female parts played by men developed in the time between 1629 and 1673. During the Genroku Era (1688–1703), considered as the golden age of Kabuki, the structure and style of the Kabuki play was formalized. During the eighteenth century, the Kabuki drama, as well as a related form of puppet theater (*ningyō jōruri*), was the most popular form of public entertainment, and the roofed, wooden style theater buildings studied in this survey had reached their final characteristic.

Kabuki performances were all-day activities from morning to sunset. Either different plays where performed in succession, or one full-length play, consisting of five acts, was performed. Particular collections of plays have evolved as a standard repertoire. The acting and dancing during a Kabuki play is accompanied by different styles of music on and off stage. Slightly curved rectangular woodblocks (*ki* or *hyoshigi*) are struck in a varitey of rythmical patterns to indicate the beginning or the end of an act or play. A second set of woodblocks (*tsuke*) is struck on a flat board to accompany the characteristical *mie* poses. A form of background music and sound effects (*geza*) is played behind a slatted wall on the left side of the stage, while different musical ensembles can be found on stage, depending on the style of a play. They can include a singer narrating parts of the story (*chobo*) accompanied by a musician playing on a three-stringed lute instrument (*shamisen*), or an orchestra with a varying number of musicians lined up on stage (*debayashi*) [1,2,3,4,5].

2. Description of the theaters

2.1. General structure

Kabuki theaters, now usually called *gekijō*, were in the past referred to as *shibai goya*, a rather derogative term for the “large built play huts” of the newly established working class entertainment. They had reached their mature architectural form by the late eighteenth century, containing certain

Table I. Architectural features of the surveyed halls, including room volume (V) and audience capacity (N).

	Year of completion	V [m³]	N	V/N [m³]	Proscenium Width [m]	Mainfloor Width W [m]	Mainfloor Length L [m]	Aspect Ratio L/W
Yachiyo-za	1910	1648	500	3.3	13.2	19.7	14.8	0.75
Murakuni-za	1882	1195	200	6.0	10.6	16.2	11.0	0.68
Kaho Gekijō	1921	3787	1200	3.2	18.6	21.3	20.3	0.95
Kanamaru-za	1835	2650	800	3.3	14.4	18.9	15.6	0.82
Hōō-za	1827	790	600	1.3	11.2	17.6	11.2	0.64

features which differ from the conventional Western theater and stage configuration [6,7]:

(a) A long, raised platform (*hanamichi*) approximately 1.5 m wide running from the rear of the auditorium to the stage on the left side (seen from the audience), as well as a smaller second platform (*kari-hanamichi*) on the right. The hanamichi is an important acting area and can be considered as a part of the stage.
(b) Two different types of audience areas: One located between the two hanamichi aisles (*masu-seki*), one on both sides of the orchestra (*sajiki*), corresponding to boxes in the Western theater. The audience sits on cushioned rice straw mats (*tatami*), allowing them to turn – more flexible then in a fixed western seating arrangement – to the part of the stage where the actors are currently present. During a performance, the audience sits on flat floor cushions (*zabuton*) on the tatami mats.
(c) A manually operated, revolving stage (*mawaributai*) used for the change of scenes. This can occur with lowered stage lights (*anten*) or with the lights left on (*meiten*).

2.2. Theater details

Although only two of the theaters examined here were originally built in the Edo period (Hōō-za, Kanamaru-za), all of them show the characteristic features described above:

2.2.1. Kompira Ōshibai

The Kompira Ōshibai (Fig. I) is the oldest extant example of Edo-period Kabuki architecture [8]. Built in 1835 in Kotohira, Kagawa Prefecture, which was an entertainment center from the time of the Genroku period, the theater was modelled after one of the major theaters in Osaka at the time (Onishi Shibai). Having been renamed several times by different owners, it was finally named Kanamaru-za in 1900. It was restored and moved to the less-crowded outskirts of the city in 1976 and recognized as a National Designated Important Cultural Property.

Figure I. Interior of the Kompira Oshibai with the main hanamichi on the left and the kari-hanamichi on the right.

2.2.2. Hōō-za

The Hōō-za, located in the city of Gero (Gifu prefecture) is the smallest of the theaters considered in this investigation. Originally a nearby shrine stage, it was moved to its current location and turned into a theater in 1827 by local residents. A major renovation occurred in 1883. It was designated as a Gifu Prefecture Tangible Folk Cultural Property.

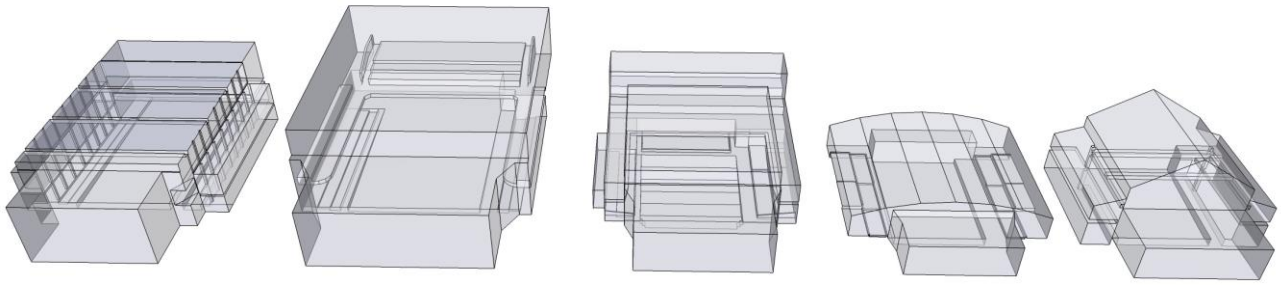

Figure II. Geometric models of the five theaters representing the actual dimensions. From left to right: Kanamaru-za, Kaho Gekijō, Yachiyo-za, Hōō-za, Murakuni-za.

2.2.3. Yachiyo-za

The Yachiyo-za was built with the support of the Yamaga Chamber of Commerce and Industry in 1910, with the idea of inviting clients for customer relationship purposes. At the same time, it served the cultural interests of a prosperous community in the northern area of the Kumamoto Prefecture. The Yachiyo-za opened in 1911.

2.2.4. Murakuni-za

Built in 1877 on the grounds of the Murakuni Shrine, the Murakuni-za was constructed by shrine parishioners to house performances of kabuki as an offering to the enshrined deity. It was completely restored in 2009 and is designated as a National Important Tangible Folk Cultural Property.

2.2.5. Kaho Gekijō

In 1921 a playhouse named Nakaza was built in Iizuka city in Fukuoka prefecture. After being destroyed by fire, it was rebuilt and renamed Kaho Gekijō in 1931. The original Nakaza theater was modelled after the Nakaza theater in Osaka and was a much larger, 3 storey structure. The parameters calculated in this survey represent the current condition after the reconstruction in 1931.

3. Measurements

The measurement results presented here were collected during a larger measurement campaign, which has already been presented in Japanese [9,10,11,12]. Impulse response measurements were performed in all rooms using a FFT-based measurement system with swept sine excitation, a dodecahedron speaker as sound source [13] placed 2 m behind the edge of the stage, and a diffuse field calibrated measurement microphone at 14 positions in the theaters. The source and receiver positions for the measurements (as well as the simulations) are shown in Figure III. The floor cusions (*zabuton*) were removed in all theaters for the measurements of the unoccupied conditions.

Table II. Absorption coefficients applied to the stage and the hanamichi, the unoccupied tatami mats, and the occupied tatami mats. The specified scattering at 707 Hz are in the software extrapolated to a frequency function of rising scattering values increasing with frequency.

	Center frequency of band [Hz]						Scattering coefficient
	125	250	500	1000	2000	4000	at 707 Hz
Stage, Hamanichi [1)]	0.25	0.17	0.12	0.09	0.10	0.05	0.05
Tatami [2)]	0.17	0.24	0.49	0.70	0.64	0.86	0.30
Tatami occupied [3)]	0.24	0.40	0.78	0.98	0.96	0.87	0.60

[1)] In-Situ Measurements, NHK, [2)] In-Situ Measurements, YAB Corporation in February 2013 [3)] M. Heckl, H.A. Müller: Taschenbuch der Technischen Akustik, Berlin: Springer Verlag (1994), p. 612

Table III. Room acoustic parameters for the five theater without audience derived from the measured impulse responses in the unoccupied condition (U) and with audience derived from the simulated impulse responses (O). EDT_m, $C_{80,m}$, $D_{50,m}$ are derived from the measured impulse responses for the unoccupied case. G_m $J_{LF,m}$ and $L_{j,m}$ have been derived from the simulated impulse responses for both cases. The single number values are averages for the octave bands suggested by ISO 3382-1:2009

	EDT_m [s]		G_m [dB]		$C_{80,m}$ [dB]		$D_{50,m}$		$J_{LF,m}$		$L_{j,m}$ [dB]	
	U	O	U	O	U	O	U	O	U	O	U	O
Yachiyo-za	0.6	0.4	8.2	7.5	8.2	10.8	0.74	0.85	0.22	0.21	-1.9	-2.0
Murakuni-za	0.9	0.5	9.9	8.4	5.7	11.1	0.69	0.84	0.19	0.18	-1.4	-1.8
Kaho Gekijō	0.9	0.5	6.3	5.5	5.4	9.3	0.61	0.80	0.19	0.19	-1.5	-1.6
Kanamaru-za	0.9	0.7	8.3	7.4	5.2	7.4	0.63	0.72	0.19	0.19	-1.3	-1.5
Hōō-za	0.5	0.3	9.0	8.2	9.9	13.2	0.78	0.89	0.19	0.18	-2.2	-2.5

4. Simulations

The simulations for the occupied condition of the selected venues were performed with a software for room acoustical simulation [14]. 3D models were created based on architectural drawings, pictures and measurements in the actual theaters. The five models are shown to scale in Figure II. The absorption coefficients used for the stage and the hanamichi, as well as the occupied and unoccupied audience area are given in Table III. The stagehouse was not comepletely included in all models but cut off at the point of the visible stage sets and a constant absorption coefficient of $\alpha = 0.8$, with a scattering coefficient of $s = 0.5$ assigned to the boundary surfaces. A residual absorption parameter was assigned to the remaining surfaces and adjusted so that the reverberation time in these models would meet the room average of the reverberation times derived from the measurements within a just noticeable difference as suggested in ISO 3382-1:2009 [15]. The scattering coefficients were set according to the suggestions in [16]. An omnidirectional source was placed on stage and listener positions were inserted corresponding to the position and height of the source and microphone positions of the actual measurements.

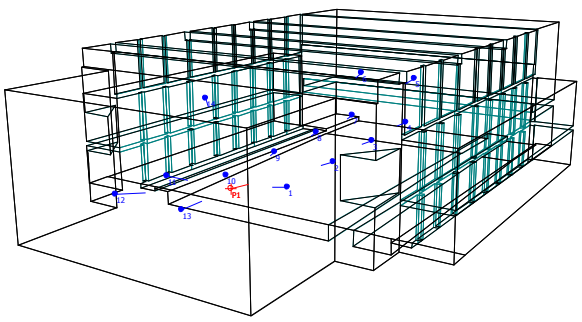

Figure III. Geometric model indicating the source and receiver positions used in the measurements and the simulations respectively.

5. Acoustical parameters

Room acoustical parameters according to ISO 3382-1:2009 were calculated from the measured and the simulated impulse responses:

(1) The sound strength G (dB) as a predictor for the subjective loudness
(2) The reverberation time T_{30} (s) as a measure for the duration of reverberation
(3) The early decay time EDT (s) as a predictor for perceived reverberance
(4) The definition D_{50} (early to total sound energy ratio) as a predictor for speech clarity
(5) The clarity C_{80} (dB) as a predictor for perceived transparency with music
(6) The early lateral energy fraction J_{LF} as a predictor for the apparent source width (ASW)
(7) The late lateral sound level L_j (dB) as a predictor for the listener envelopment (LEV)

In addition to these parameters, the speech transmission index (STI) has been determined according to the indirect method described in IEC 60268-16:2011 [17]. For all parameters (except STI), impulse responses generated with a 3-way

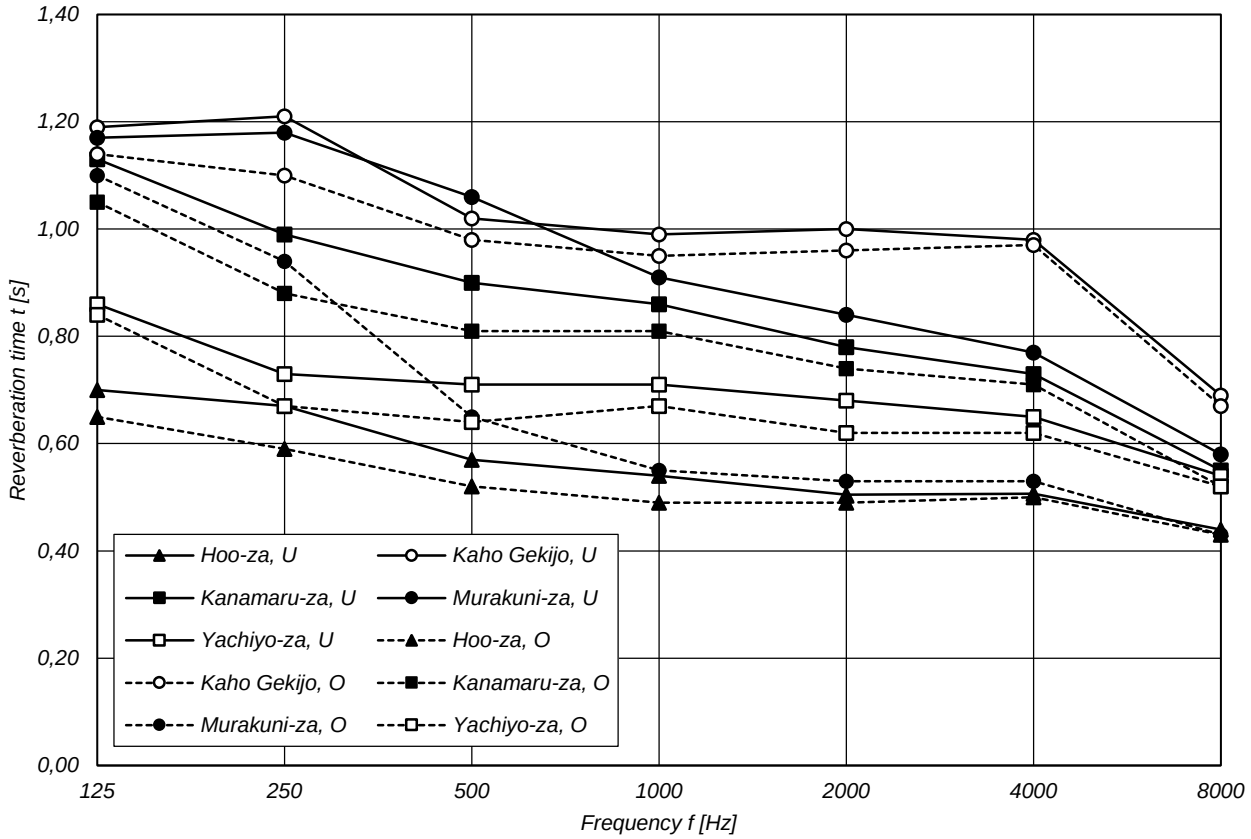

Figure IV. Room average reverberation times for the 5 theaters for the unoccupied case (U) derived from the measurements and the occupied case (O) derived from the simulations.

dodecahedron loudspeaker (in the measurement) and a perfectly omnidirectional loudspeaker (in the simulation) were used. The STI values were calculated from the impulse responses simulated with a source directivity of a male speaker with normal vocal effort according to [18]. For the background noise level in the simulation the NC 15 curve (27.1 dBA) was applied.

Table IV. Room average and standard deviation of the Speech Transmission Index (STI) for the 5 theaters.

	STI	
	U	O
Yachiyo-za	0,68 ± 0,04	0,70 ± 0,04
Murakuni-za	0,63 ± 0,05	0,70 ± 0,06
Kaho Gekijō	0,62 ± 0,05	0,63 ± 0,05
Kanamaru-za	0,62 ± 0,06	0,64 ± 0,06
Hōō-za	0,72 ± 0,04	0,74 ± 0,04

6. Results

Figure IV shows the frequency-dependent reverberation times for the 5 theaters as an average value of all listener positions. The values for the unoccupied cases are derived from the measurement, while values for the occupied case are derived from the simulation. Differences in reverberation times between the occupied and the unoccupied condition are relatively small due to the absorption properties of the tatami mats covering the audience area during the measurements of the unoccupied cases, except for the Murakuni-za, where the difference is bigger since no tatami mats are covering the wooden audience area finishing. The occupied reverberation times are in the range of 0.5–1.0 s, which includes the range of recommended values for European drama theaetre [19]. The room acoustical conditions, as shown in Table III and IV for the occupied (O) and the unoccupied (U) condition, seem favourable for speech, with $D_{50,m}$ values in the range of 0.6–0.8 for the unoccupied case and 0.7–0.9 for the occupied case. The sound strength G_m values are in the range of 5.5–8.4 dB providing considerable support for the sound sources in all theaters. The oldest and

smallest theaters show the highest values, while the newest Kaho Gekijō shows the lowest value. The Speech Transmission Indices (STI), shown in Table IV as room average ± standard deviation, demonstrate the rather homogeneous listening conditions for the complete audience area, with 'good' or 'high' speech intelligibility as recommended by [16] for theaters or lecture halls.

7. Conclusions

With the 5 theaters examined in this survey, a representative sample of the extant wooden style Kabuki theaters has been studied, including measurements in the empty rooms and simulations of the occupied condition. From a western point of view the room acoustical conditions seem favourable for speech rather than for music, with rather homogeneous listening conditions over the complete audience area, reverberation times at mid-frequencies between 0.5 and 1.0 s, Definition values of $D_{50,m} > 0.7$ for the occupied condition, and a strong acoustical support, with sound strength values of $G_m > 5.5$ dB. The acoustical properties, along with an interior design directly involving the audience into the happening on stage, thus are suitable in order to support a sense of closeness and intimacy which is constitutive for the concept of Kabuki theaters in general.

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