ACOUSTICS OF TRADITIONAL CHINESE THEATERS

W. Chiang,. National Taiwan University of Science and Technology, Taipei, Taiwan
W. Lin National Taiwan University of Science and Technology, Taipei, Taiwan
Y. Hsu Tung-Fang Institute of Technology, Kaohsiung County, Taiwan

Acoustical measurements were conducted in the theaters built in the eighteenth and nineteenth centuries, including fully covered indoor theaters, courtyard-type theaters inside public buildings, and the theaters integrated with Chinese gardens. Unoccupied reverberation time is in the range of 0.6 to 1.1 s. Computer and scale modeling were employed to analyze the effect of architectural features on acoustical measures for courtyard-type theaters. The impact of stage ceiling is crucial on early support (ST1) while the size and height of the courtyard are import in maintaining sufficient sound strength and early decay time for the audience. Sound strength of the room and listening direction are the major factors that influence the overall impression of Beijing Opera.

1 INTRODUCTION

Compared to the understanding of room acoustics in western concert halls and theaters, little is known about traditional Chinese theaters. Most of the preserved theatrical buildings were built in the eighteenth and nineteenth centuries although the oldest ones can be traced back to the thirteenth century. Extensive surveys in documenting these buildings have been initiated by Wang from both architectural and acoustical perspectives. Based on spatial composition he categorized the theaters to three types: the amphitheater type, the courtyard type, and the auditorium type.

As most traditional Chinese architectures, the theaters normally use wooden column-and-beam structures. Walls are normally wood but in some cases can be made of earth sandwiched between boards and then plastered. Wood brackets supporting the crossbeams, coffers and openings on walls, and highly modulated window frames and ceilings provide sound diffusions, especially in the frequency range of 1000 to 2000 Hz bands.

Chinese traditional opera is a unique art form that combines singing, music, dialogue, pantomime and martial arts. The signing voice is the most important no matter for Beijing Opera that uses Mandarin or most of the other varieties that use local dialects and melodies. The acoustical concerns are multi-dimensional. Limited surveys by Xiang suggested an optimum mid-frequency reverberation in the range of 1.0 s to 1.2 s to balance between intelligibility for speech and liveness for music. Adequate loudness for remote seats and balance between the singing voice and the accompaniment should be provided. Bass sounds and lateral reflections are of lesser significance. Symbolic acting requires a small size stage that provided good acoustical support and communication between the actors and the accompanying group. However, problems might arise when actors faced away across the trust stage.

This paper reports the results from several studies to understand the acoustical condition in tradition Chinese theaters. Field surveys were followed by acoustical modeling and subjective assessment based on simulated singing of Chinese Opera.

2 FIELD SURVEY

In general, field measured data show that the acoustical conditions in the traditional venues are slightly drier than the suggested conditions. Nevertheless, the small size of the existing theaters provides great speech intelligibility and adequate loudness. Early support (ST1) varies significantly due to the difference in plane size and height of the stage ceiling. At certain stages ST1 in the 250 and 500 Hz bands also varies significantly when moving the microphone and speaker location, indicating sound focusing due to the dome shaped stage ceiling. The wood brackets in these venues only diffuse sound at high frequency.

Auditorium type theaters were built mostly in guildhalls and residences of the nobility. A typical theater has a relatively small thrust stage in a near square hall space. The average room volume is in the range of 2000 to 3000 m^3 with ceiling height approximately between of 6 to 8 m. Huguang Guildhall, Beijing is among a few theaters that are still operated commercially (figure 1). The audiences are equipped with small tables for serving tea and desserts. Measurements were taken using the B&K Dirac software system. The average unoccupied mid-frequency early decay time (EDT) and sound strength (G) are 0.94 s and 9.8 dB, respectively.

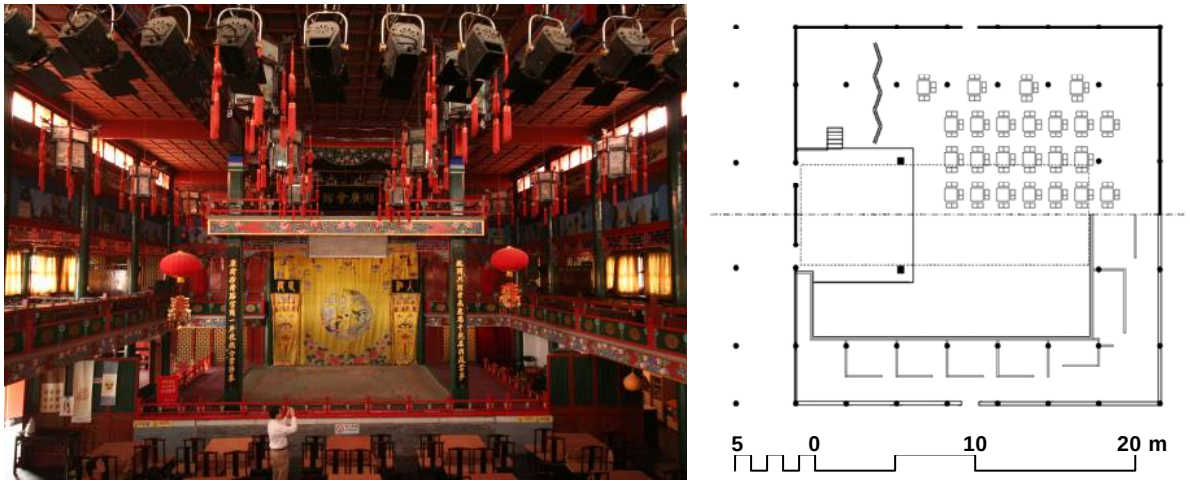

Figure 1. Huguang Guildhall, Beijing.

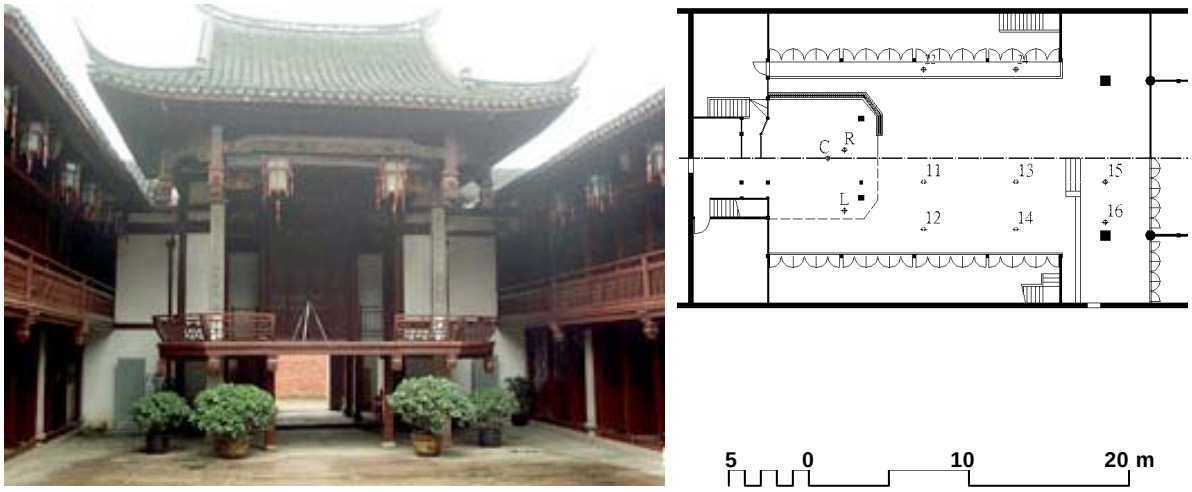

Figure 2. Sanshan Guildhall, Shanghai.

Courtyard-type theaters were built in temples and guildhalls in east and south coastal areas of China. A normally raised stage is attached to a courtyard surrounded by walls or covered galleries which is generally symmetrical in plan. The stage floor is raised to one-story high to allow for access underneath and to provide good sightlines for the standing audiences in the courtyard. Both architectural and acoustical characteristics of the theaters are similar to the ones of Elizabethan theaters although the latter are generally greater in size. Sanshan Guildhall, Shanghai (figure 2) is a typical courtyard type theater with side balconies attached to the two-story wing rooms. With the wing rooms closed, the average unoccupied mid-frequency EDT and G are 0.95 s and 7.6 dB, respectively.

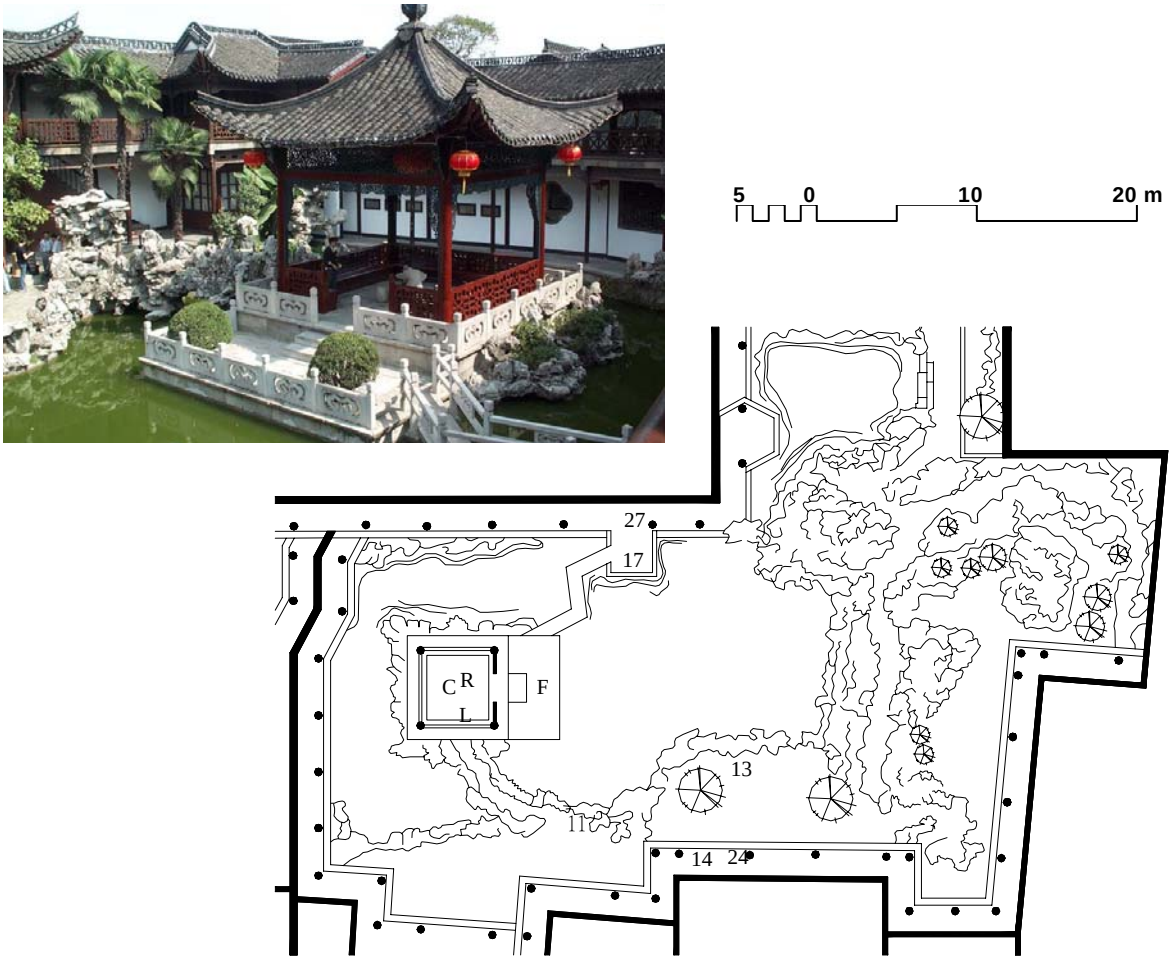

Figure 3. Jixiao Manor in He Yuan, Yangzhou

The theater integrated with privately owned Chinese garden can be considered as a special variation of the courtyard type theater. Geometrical composition of the theaters is rather irregular and varies significantly from case to case because of water, rocks, bridges, walls, and vegetation in the garden. The stage floor area is even smaller than the areas of the previous types, allowing only one or two performers most time. Because the stage is not raised and not directly attached with the back wall, sound strength (G) of the theater integrated with garden is generally lower than the values of the theaters in temples and guildhalls. Jixiao Manor in He Yuan (JM), Yangzhou represents one of the well maintained theaters built in the nineteenth century (figure 3). A large portion of ground is covered with a major water pool and an abundant amount of rock hills with passages and vegetation among them. The high hills rather than the wall behind them defined the rear border of the courtyard. The average unoccupied mid-frequency EDT and G are 0.80 s and 3.1 dB, respectively. With audiences restricted only to certain spots, the occupied condition is expected to be not much different from the unoccupied condition. Loudness can be problematic at some locations such receivers 13 and 14 of this theater. Measurements in other smaller theaters also indicate that there may be potential problems in sound coloration or even image shift.

3 MODEL ANALYSIS OF THE COURTYARD TYPE THEATERS

Computer analyses using Odeon 5 software package were employed to systematically analyze the effects of various architectural features on early time (EDT), sound strength (G) and early support

(ST1) for the courtyard-type theaters where the reflection density could be low with the absence of ceiling. A prototype model was built using the dimensions of Sanshan Guildhall. The ranges for various architectural features were determined based the data from the theaters surveyed. Measurements in 1/16 scale models were conducted verify the effect associated diffusion and diffractions. The decorations on the stage ceiling and on the walls surrounding the courtyard were also made following the ones appeared in Sanshan Guildhall (figure 4 and 5). The directional pattern for the scaled-up frequency of the sound source, a Grozier GTS51 high-voltage spark, is considered similar to a human singer.

Figure 4. Courtyard view of the 1/16 scale model showing the detailed architectural features on the walls.

Figure 5. Stage ceiling view of the 1/16 scale model showing the wood brackets.

Without considering sound diffusion, the impact of the presence of stage ceiling is crucial on ST1 but not G and EDT. By adding the ceiling with height and size set to 4 m and 45 m^2, respectively, ST1 can be raised from -13.5 dB to -9.0 dB. ST1 can also be increased by reducing ceiling height or courtyard size. EDT can be significantly increased up to 1.0 s by increasing the building height to 9 m. The other architectural factors are less important. Raising the stage floor, decreasing the courtyard size (especially the width), or increasing the overhangs around the perimeter would significant increase G. It is also found that early reflections would be blocked by the side balconies when raising the sound source above the height of the side balconies.

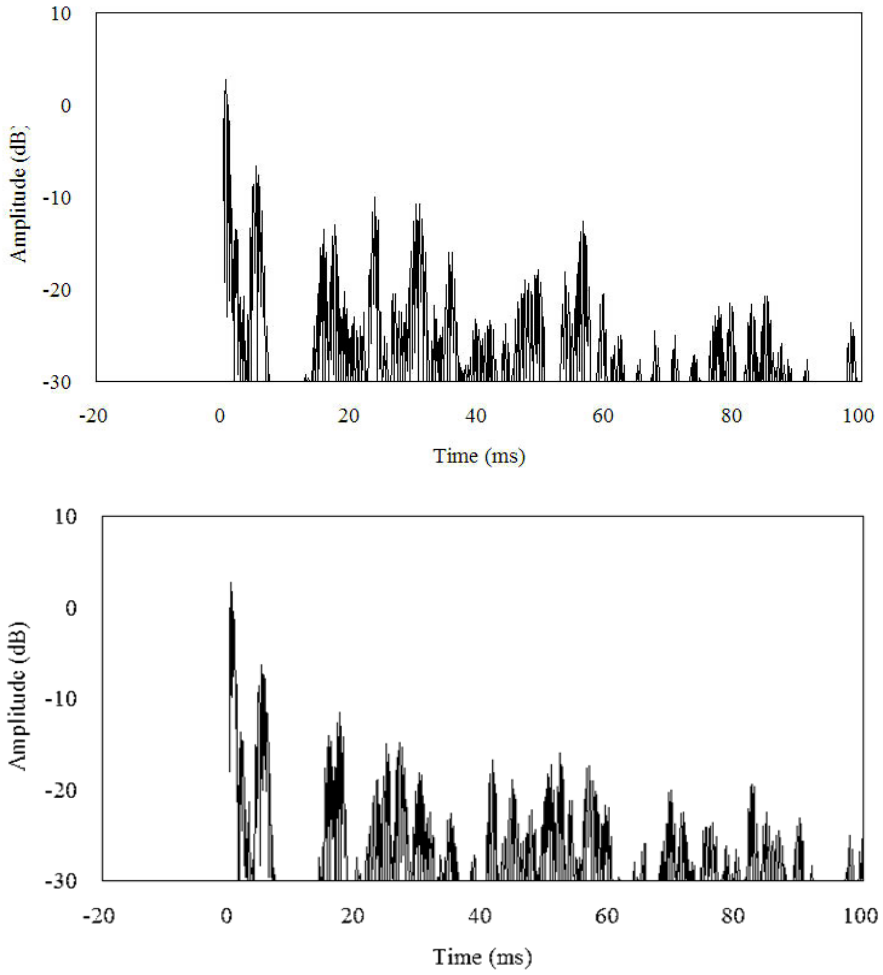

Figure 6. 1-kHz band echograms comparing the model with plane concavely shaped ceiling (top) to the model with the ceiling installed with wood brackets (bottom).

4 SUBJECTIVE ASSESSMENTS OF ACOUSTICAL ENVIEONMENTS FOR BEIJING OPERA

A preliminary study was conducted regarding subjective assessment of the acoustical environment for Beijing opera. Recording of dry solo singings and dialogues were made in a laboratory. Four professional actors were invited with each representing Sheng (main male role), Dan (female role), Jing (painted face male role), and Chou (male clown role). The music samples were convolved to music segments by using binaural impulse responses. The impulse responses were set to represent acoustical conditions with reverberation time in the range of 0.55 to 1.7 s and sound

strength in the range of 5 to 13 dB. A front listening location was also compared to a side listening location. Twelve listeners representing the general public were asked to evaluate the simulated music via headphones. The listeners were asked to answer ”yes” or “no” regarding overall impression and other subjective attributes of 72 music segments.

Sound strength and listening direction are the principle factors that determine overall impression. For the segments convolved using the dry recording on side of the actors, a sound strength of 7 dB can be used as the lower limit that corresponds with overall impression of 50 %. The effect of reverberation time is less significant. 6000 m^3 can be used as the upper limit for room volume when a thrust stage is used.

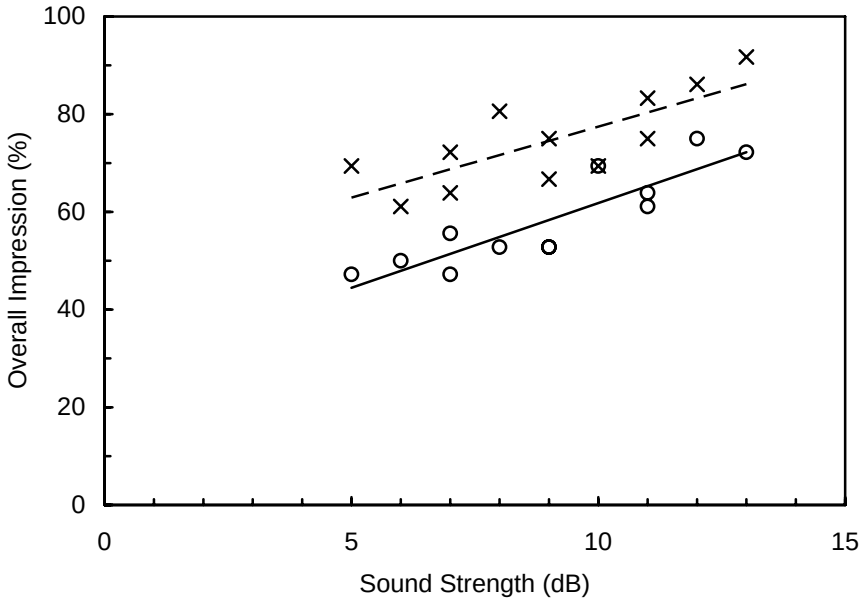

Figure 7. Overall impression as a function of mid-frequency sound strength (G) comparing the front receivers (x) to the side receivers (o). The two lines represent the line fits of the data points.

5 SUMMARY

Traditional Chinese Opera performed in modern theaters today is inevitably produced using sound amplification although unassisted singing from a trained player can be heard in a relatively large venue. This paper provides fundamental knowledge about the acoustics and traditional Chinese theaters and the associated programs by field survey, acoustical modeling, and psycho-acoustic experiments. Continuing studies will be conducted to provide further understanding to assist architects and acousticians in properly using the existing historical venues and designing new ones.

6 REFERENCES

1. Liao, B. *The History of Ancient Chinese Theaters*, (in Chinese) (Chung Cho, Chengcho, 1997).
2. Wang, J.Q. ”Acoustics of Chinese Traditional Theaters”, First Pan-American/Iberian Meeting on Acoustics, December, Cancun, Mexico. (2000).
3. Wang, J.Q. “A primary study of the acoustics of Chinese traditional theatrical buildings (in Chinese)”, *Technical Acoustics*, ***21*** (1/2), 74-79 (2002).

4. Xiang, D. *Practical Architectural Acoustics*, (in Chinese) (China Building Industry, Beijing, 1992).
5. Cheng, D. *Chinese Music Instrument* (in Chinese), (ShengYun, Taipei: 1985).
6. Wang, C. *Guildhall Theaters and Drama*, (in Chinese) (Wen Jing, Taipei, 2000).
7. Hsu, Y., Chiang, W., Tsai, J., and Wang, J. "Acoustical Measurements of Courtyard-Type Traditional Chinese Theater in East China", AES 21st International Conference for Architectural Acoustics and Sound Reinforcement, June, St. Petersburg, Russia, (2002).
8. Richardson, R. and Shield, B.M. "Acoustic measurement of Shakespeare's Globe Theater, London", Forum Acusticum 99, March, Berlin, Germany. (1999).
9. Barron, M. *Auditorium Acoustics* (E& FN Spon, London, 1993)
10. Charles, J. *Chinese Garden*, (Academy Editions, London, 1978).
11. Lee, C. *Lin Family Residence at Panchiao*, (Hsiung Shih Art Books CO. Ltd, Taipei, 1987).
12. Tseng, Y. *Traditional Taiwan Drama*. (in Chinese) (Tong Hwa CO. Ltd., Taipei, 1997).
13. Tsai, J,. "Acoustic Measurement of Courtyard-Type Traditional Chinese Theater (in Chinese)", A Master's Thesis of National Taiwan University of Science and Technology (2002).