台南奇美樹谷園區音樂廳之聲響性能探討

Acoustical Design of Chi Mei Concert Hall

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摘要

奇美樹谷園區之廳堂是以音樂為演出性質為主之多功能表演場所。可行的聲響性能之設計，透過電腦模擬軟體之分析來了解廳內觀眾席區之聲響分佈狀況。主要廳內聲響性能設計內容包括舞台周邊展開之牆體形狀與上方活動反射板之設置。另外，多功能表演設施之聲響性能利用吸聲布幕與擴散材料之應用，達到使用目標。利用舞台上方之活動反射板之裝置來達到聲樂溝通與平衡。客觀物理測量之脈衝響應也作為參數分析之能量依據。

關鍵字：多功能廳堂、電腦模擬、客觀量測

Abstract

Chi Mei Concert Hall is a typical multi-purpose hall primarily intended for concerts. A three dimensional ray tracing computer simulation was used to provide sound energy distribution on the audience area of the hall, realistic design have been performed. This results in sprayed platform boundary walls and the moveable reflector. Variable acoustics have been obtained through the use of absorptive draperies and diffusive elements. In addition, improving the communication between the musicians by utilizing the moveable reflector on the stage has been constructed. Objective measurements of impulse response are also reported.

Keywords: Multi-purpose hall, Computer simulation, Objective measurements.

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1. INTRODUCTION

This paper presents the acoustic design principles for the Chi Mei Concert Hall in Tree Valley Park of Tainan. A number of major acoustical features have been employed in order to provide a hall which meets the various criteria for a venue designed to accommodate an international and multi-purpose repertoire of events. The paper begins with the general design objectives for the Concert hall. Following sections are dedicated to detailed studies concentrating on the major design components: side reverberation chambers. The results presented here not only have been used to verify the design scheme concept, simple field verifications have also achieved in the newly built in order to characterize in the acoustics of the hall. The measurements were made with a simple setup, and data were treated with Dirac analysis packages. The Chi Mei Concert Hall is opened in September 2008 and has always been considered as the premier recital venue in Tainan County. The volume of the hall is $6820m^3$, and equipped the hall with acoustical curtains by modifying its acoustical characteristics. A room form was developed as prototype that had overall proportion and volume similar to the 400 seats Gewandhaus concert hall in Leipzig in 1781. The hall is a rectangular "shoebox" shape like Amsterdam's Concertgebouw and Vienna's Musikverein (Beranek, 1993).

2. GENERAL DESIGN

The 460-seat concert hall will serve a variety of uses: Concert, amplified musicals, drama and speech events. The acoustic requirements for these usages are very different, in terms of reverberation time. There is especially a requirement for additional reverberation for concerts when compared to amplified events. Amplified usage requires a shorter reverberation time and additional acoustic volume for loudness control. The proposed design concept achieves the required variability with an additional variable acoustical absorption (draperies) were hided behind the sides grillages of the hall. One row of the side balcony which is surrounded the stage and projected to the main auditorium is also shown here. They were installed in order to increase acoustical and visual intimacy. Table 1 shows the architectural detail of Chi Mei Concert Hall. The plan shape and section is a shoe-box type as shown in Figure 1. Figure 2 shows the front view of the completed Chi Mei Concert Hall.

Table1. Architectural details of Chi Mei Concert Hall

Use	Concert, amplified musicals, drama and speech events
Plan type	Shoebox
Seats	Total 460 seats (2nd floor side balcony:60)
Dimension	W × L × H: 20 m × 32 m × 14 m
Volume	6820 M^3
Stage area	Depth:14 m, Height: 14 m, Area: 140 m^2
Adjustable elements	Absorptive draperies, orchestra reflector

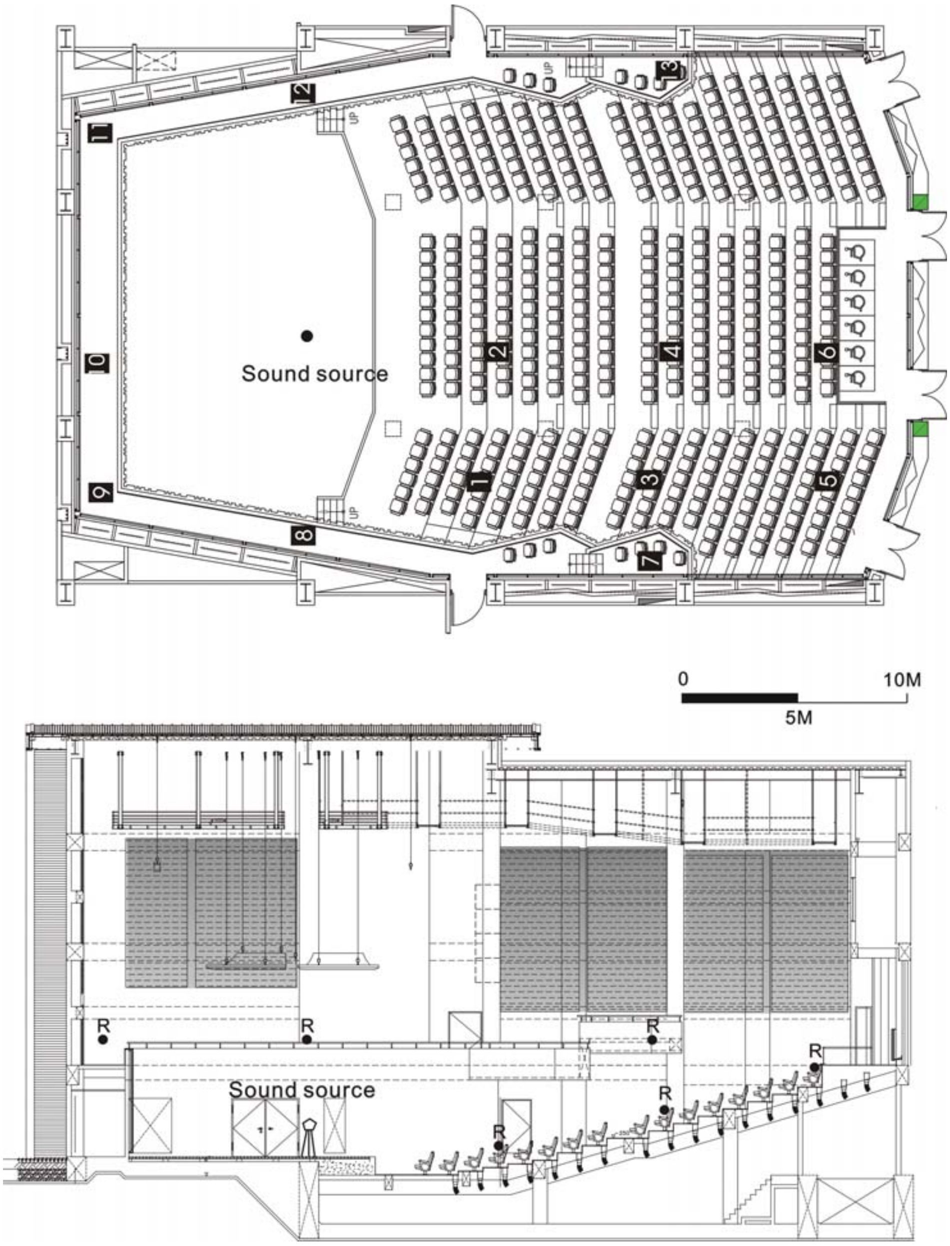

Fig.1. Longitudinal section and plan drawings of Chi Mei Concert Hall showing the locations of sound source and receivers.

Fig.2. View toward stage of completed Chi Mei Concert Hall

3. ACOUSTICAL DESIGN BRIEF

The brief for the required acoustics of the main auditorium must have optimizing approaches for an unoccupied reverberation time of 1.8s for orchestra performance. A hard reflective rough-surface of concrete on the side wall with 20 to 30cm -wide wood strips were installed in order to reduce strong and scattered reflections to the main auditorium. The maximum-length sequence (MLS) diffusers on the side walls were installed at 315cm above the floor to make a high frequency of scattered sound field. Low frequency diffusion was induced by the shape of the side balcony and balcony front. Double layers of plasterboard ceiling reflectors have a hard curved surface to support the remote reflections and musical balance among the players. The locations of the reflectors approximately cover the main directions for sounds from higher strings, wood winds, and singers that are radiated towards the audience. The 250 m^2 of moveable absorbing draperies were installed on the side walls between wood strip and rough concrete.

4. COMPUTER SIMULATION

The simulation was performed by using the upgraded Odeon 6.5 software package that can handle energy parameters of ray tracing calculation and was used to validate the schematic concept of using the curve reflectors. The number of rays was set to 20000 and the truncation time of calculation was set to 2000 ms. The source was on the central axis and 3-m from the front edge of the platform. A omni-directivity sound and violin source provided by the software package and was used occasionally as references. As shown in figure 3, the coverage of 1st order reflections can be evenly distributed to the stage and the frontal audience by only one side of the proposed upper reflectors. A double layers of gypsum board and a 0.1 scattering factor were assigned to the side and rear walls. Occupied seating with medium upholstery was used for the audience and a 0.7 scattering factor was assigned. Furthermore, acoustics parameters were proposed design target values by computer simulation for the energy parameters EDT, G, D50 and C80.

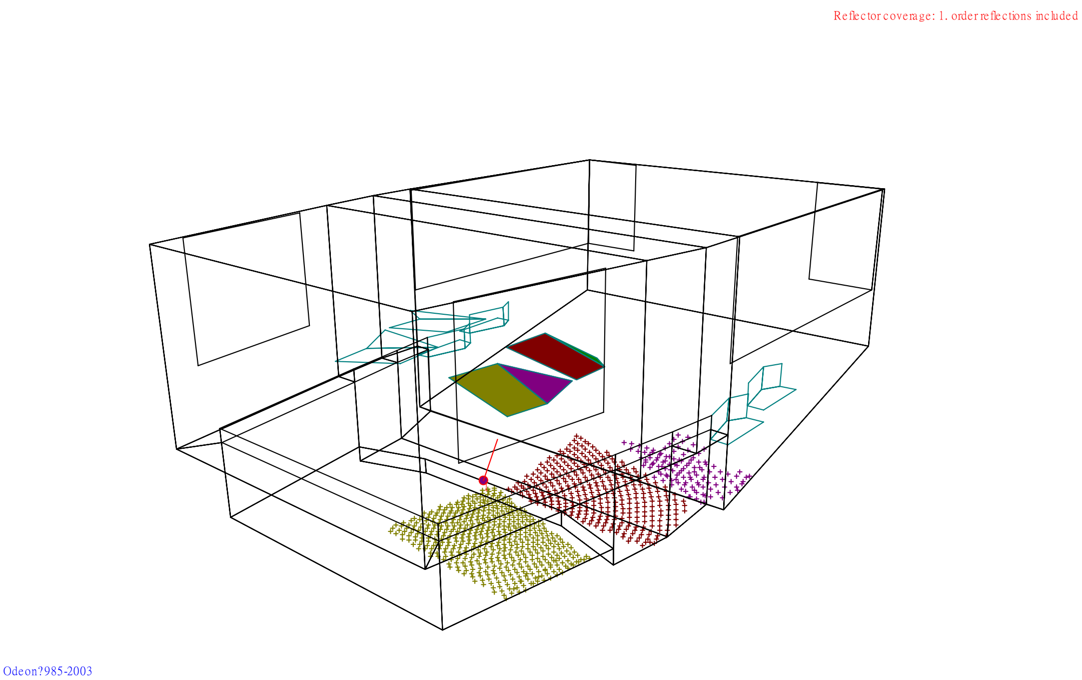

Fig.3. Simulated 1st order reflection coverage from one side of the upper reflectors.

5. FIELD VERIFACTION

Hence the relevant standards for the measurement of real field acoustics (ISO 3382) require that an omni-directional sound source be used. The instruments were set up and calibrated: The Brüel & Kjaer Omni-Power sound source Type 4292 was used as a cluster of 12 loudspeakers in a dodecahedral configuration that radiates sound evenly with a spherical distribution. Receivers were achieved with a ½" single microphone Brüel & Kjaer Type 4191and a preamplifier B&K 2669. The DIRAC 4.0 was an attempt to analyze how acoustical indices, such as RT30, C80, D50, Ts and EDT, are derived from the impulse response which is based on the International Standard ISO 3382 (Bradley, 2004), using the integrated impulse response method. Measurements of impulse response were conducted within a frequency of 63 Hz up to 8 KHz with the e-sweep sine signal. The 13 receiver positions were chosen one side of seating which were symmetrically distributed of the hall (see in Fig.1). The numeric data for the acoustical measurements were summarized in Table 2 when all the acoustical draperies are taken off. The reverberation time at mid frequencies resulted about 1.8 s.

Table 2 Overall values obtained in Chi Mei Concert Hall with unoccupied seating

Frequency	63	125	250	500	1000	2000	4000	8000
T30 [s]	2.29	2.16	2.02	1.94	1.77	1.58	1.40	1.18
C80 [dB]	0.9	-2.0	-0.5	-0.1	0.2	0.7	1.2	2.1
D50 [%]	0.45	0.22	0.35	0.35	0.38	0.39	0.41	0.45
Ts [ms]	153.2	171.5	137.8	124.8	119.3	106.8	97.1	84.6
EDT [s]	2.01	2.23	1.98	1.80	1.72	1.56	1.41	1.17

6. DISCUSSION

When comparing the reverberation time (T30) and early decay time (EDT)of the concert configuration with that of the drama configuration in the hall difference usage with 250 m^2 absorptive draperies. The reverberation times and early decay time derived from the filed measurements for the concert configuration and drama configuration are shown in Fig.4. Reverberation time averaged from 250 Hz through 4 kHz was decreased by approximately 15 % when the draperies were totally opened. EDT averaged from 250 Hz through 1 kHz was decreased by 28 % with the draperies opened. The influence of these draperies in the hall was, however, more significant for EDT.

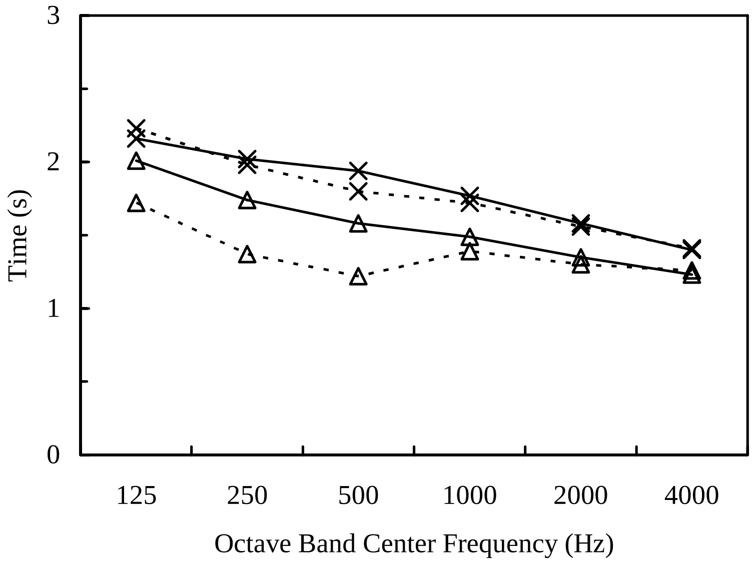

Fig.4. Reverberation time (T30) (solid line) and early decay time (EDT) (dotted line) derived from field measurements as a function of frequency band comparing the concert configuration (X) and drama configuration (Δ).

In order to realize the influence of the position of sound source and directivity patterns, an e-sweep sine signal was emitted from at a height Auratone 4-inch speaker aimed at an elevation angle of 0 º. The speaker was placed on central axis at 3 m from the stage platform line was supported on a tripod at 1.5 m above the floor. Avoid to diffusive hall receiving the more energy from the direct sound, receiver positions at a distance of 7.5 m which were surrounded the stage on the balcony at 30 º, 90 º, and 180 º azimuth angles from the central axis of the hall (See in Fig. 1). Figure 5 shows Clarity *C80* taken from the 30º, 90º, and 180º azimuth angles with the speaker aimed horizontally. The difference between the 30º and 180º microphone positions was 7.8 dB for frequency bands 500 Hz through 4 kHz when the speaker was aimed horizontally. As shown in figure 6, Clarity C80 was the highest at the 30 º position and the lowest at the 150 º and 210 º positions. The difference was around 5.5dB between frontal and surrounding seating.

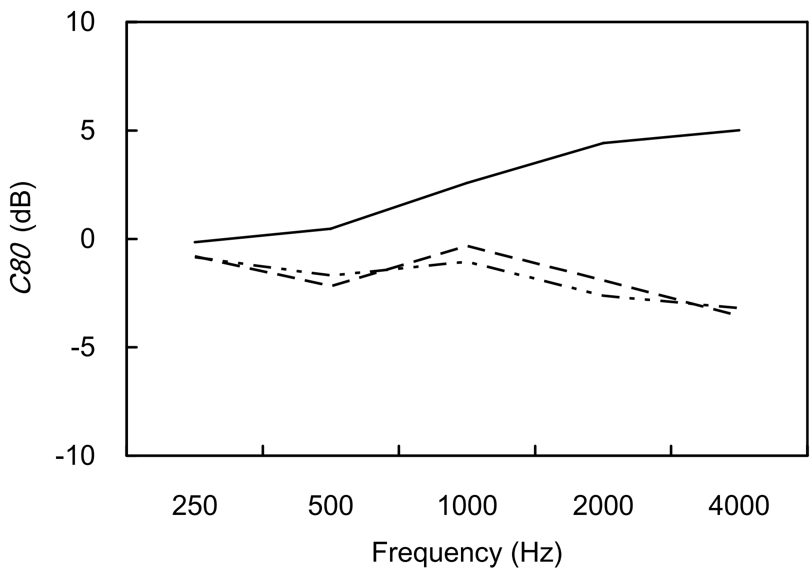

Fig.5. Clarity (C80) using an Aurotone 4-inch speaker aiming horizontal on-axis measured 7.5-m from an azimuth angle of 30º (solid line), 90 º (dashed line), and of 180º (dotted line).

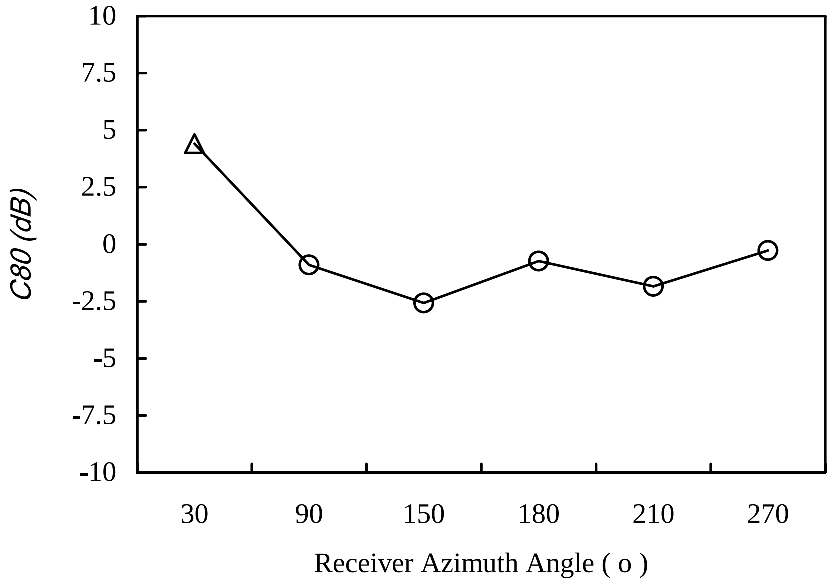

Fig.6. Clarity (C80) as a function of frontal (Δ) and surrounding (O) receivers viewing angle with frequency bands2k Hz through 8 kHz.

7. ACKNOWLEDGEMENTS

The authors wish to thank Natural Acoustic, Huang Kung Huang for the helps of filed measurements, and Archasia Design Group, Architect Zhou and Project Manager Wu for the collaboration during the design phase.

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