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A mid-size concert hall with staggered terraced seating

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ABSTRACT

The new Pingtung Performing Arts Center at Southern Taiwan features a mid-size concert hall. The significant portion of seats surrounding the stage and the extra width makes it possible to use terraced seating layout. The terraces were staggered to correspond to the asymmetry of the building and to amplify the size of the reflective surfaces bounding the terraces. Inclined surfaces were also appeared on upper walls where distances between walls were shortened to provide higher order early reflections. Computer simulation was performed to adjust the angle of these diffusive and inclined surfaces to simultaneously satisfy clarity, strength, sectional balance, and stage support. The surfaces near the stage were in particular tuned to direct reflections not only to the nearby audiences at the lowest level but also to the performers and the audiences surrounding the stage.

INTRODUCTION

Terraces and surrounded stage have been introduced in mid-size concert halls recently to increase visual intimacy [1]. The mid-size concert hall is a major facility of the new Pingtung Performing Arts Center at southern Taiwan. Various schemes proposed for the competition phase through the design phases contains simple audience terraces in a rectangular outline. The seats surrounding the stage that can be alternatives used for choir makes the hall as "semi-surround". This paper reports on the development of design concept.

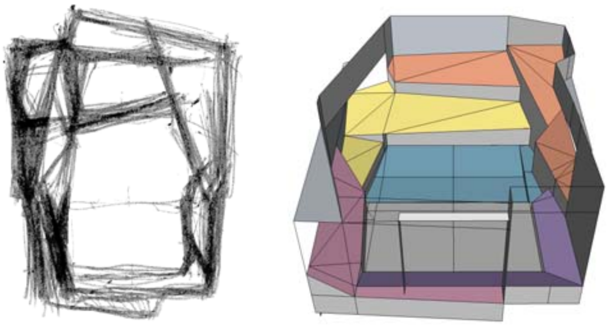

Figure 1. A sketch (left) and a 3D model (right) of the scheme proposed for the competition phase.

DERIVING THE ROOM FORM

Initial approach

An initial scheme was proposed for the competition phase that contains the proportion of the Concertgebouw, Amsterdam. The total area including audience and stage was similar to which required by the program when the under balcony area of the Concertgebouw were removed. The volume was reduced to around 14,000 m^3.

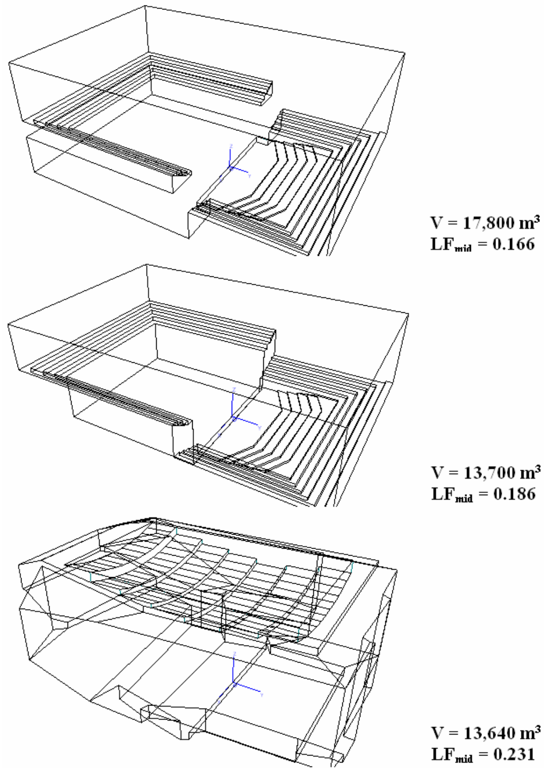

Figure 2. Computer simulated 1000-Hz band lateral energy fraction (LF) comparing a simplified Concertgebouw (top) to the scheme with removed under balcony seats (middle) and the scheme proposed for the competition phase (bottom).

Attentions were placed upon:

1. Compensated high frequency components for the seats surrounding the stage. [2]

2. Sufficient strength for the remote seats. [3]

3. Improved lateral energy for the seats in the stall and the seats on side terraces. [3]

An asymmetrical approach was taken when the architect favoured an irregular building form composed with polygon surfaces in varying sizes. The terraces and tilted reflecting panels were staggered that corresponds to the asymmetrical geometry of the foyer spaces and the entire building. This layout amplified the size of the reflective surfaces bounding the terraces and protruded upper walls. Maximum length and width of the hall were 42m and 31 m, respectively. The seat count was around 1,200.

As shown in Figure 1, two major terraces were staggered with a lower, nearer terrace on one side of the hall and a higher, farther terrace on the other side. The splayed terrace bounding walls on the two sides of the main floor not only directed energy laterally to the seats in the stall but also diagonally back to seats on the two sides of the stage. By setting the ceiling in different heights according to the geometry of the terraces, the hall volumes were partially divided that provided stronger and earlier reflections to all audiences.

Computer simulation of the schematic design was compared with the simulation of a simplified Concertgebouw with and without the under balcony area. Overall values of lateral energy fraction boosted (Figure 2).

Development of alternatives

Various alternatives were proposed for the design phase when a different firm, Artect Architects was commissioned for the job. Alternatives were developed that generally followed the shape outlined by architect. The proportion was slightly narrower and longer when compared with the scheme proposed for the competition phase. The audience floor area was slightly reduced accordingly. One side of the hall was rectangular. The other side consisted with a narrow, splayed front part where the very front of the hall was 25 m. About 3/5 of the rear section was wider with the average width around 28 m.

As shown in figure 3, three major alternatives were analyzed. The first alternative generally consisted of two staggered terraced where the inner one was on the rectangular side of the room and the outer one on the other side. The second alternative stressed on the reversely splayed wall and terrace bounding wall to counteract the splaying of the front part of the hall. The third alternative emphasized on a raised, long terrace that enlarged the reversely splayed bounding wall.

The alternatives shared some commonalities:

1. The distances between the inner terraces in front of the stage and the center point of the stage front line were controlled between 12 m to 13 m to direct early energy back to the players and to the surrounding seats.

2. An outer loop of terraces was introduced to secure early energy reflected to the inner terraces.

3. Both sides of the rear walls were splayed to compensate for the energy loss due to introducing terraces on the sides that blocked the reflection paths which would exist otherwise in rectangular halls. [4]

4. On the rectangular side of hall there were two levels of audience seating.

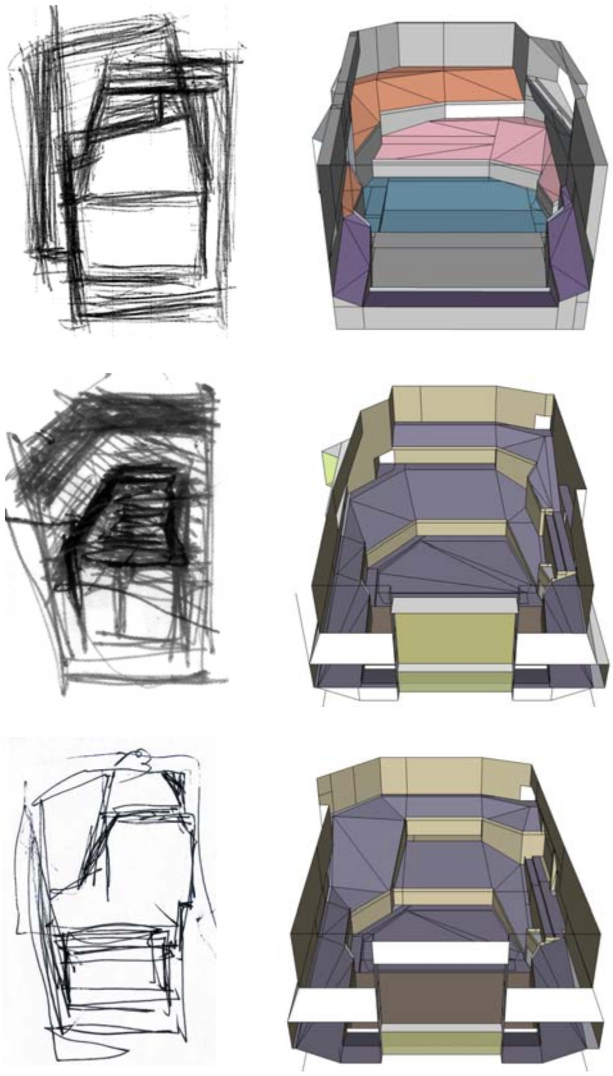

Figure 3. Sketches (left) and 3D models (right) of the alternatives proposed for the design phase.

OPTIMIZATION

Designing a surrounded concert hall with terrace seating is challenging because the quality of various parts of the audience need to be taken care individually. This requires a thorough optimization process. It's unlike designing a rectangular where the design process can be executed in a statistical manner.

In this project the optimization started with fine tuning the height difference between the inner front terrace and the terraces surrounding the stage. Taking the development of 2nd alternative as an example, the inner terrace was raised from a original scheme to secure the coverage of 1st order reflections. However, this should not be overdone; otherwise the upper terraces could be too steep.

When one side of the terrace was turned diagonally, the reflection paths to the remote seats via the side wall backing the seats would likely be blocked by the turned terrace. It is, therefore, necessary to create other paths to compensate for the energy loss. This can be realized by splaying and inclining upper parts of the side walls as indicated by Cremer [5]. Incorporating diffused, inclined surfaces above the perimeter seats could also benefit the seats with extra early energy.

Figure 4 shows the distribution of 2-kHz band strength from a voice source comparing a rectangular configuration to progressive changes of alternative 2. The configurations (middle graph) with raised inner terrace showed increased energy for the seats surrounding the stage. Nevertheless, the level of the remote seats near the corner decreased. Incorporating inclined walls and reflectors attached to the walls (bottom graph) was effective in raising the level throughout the perimeter seats.

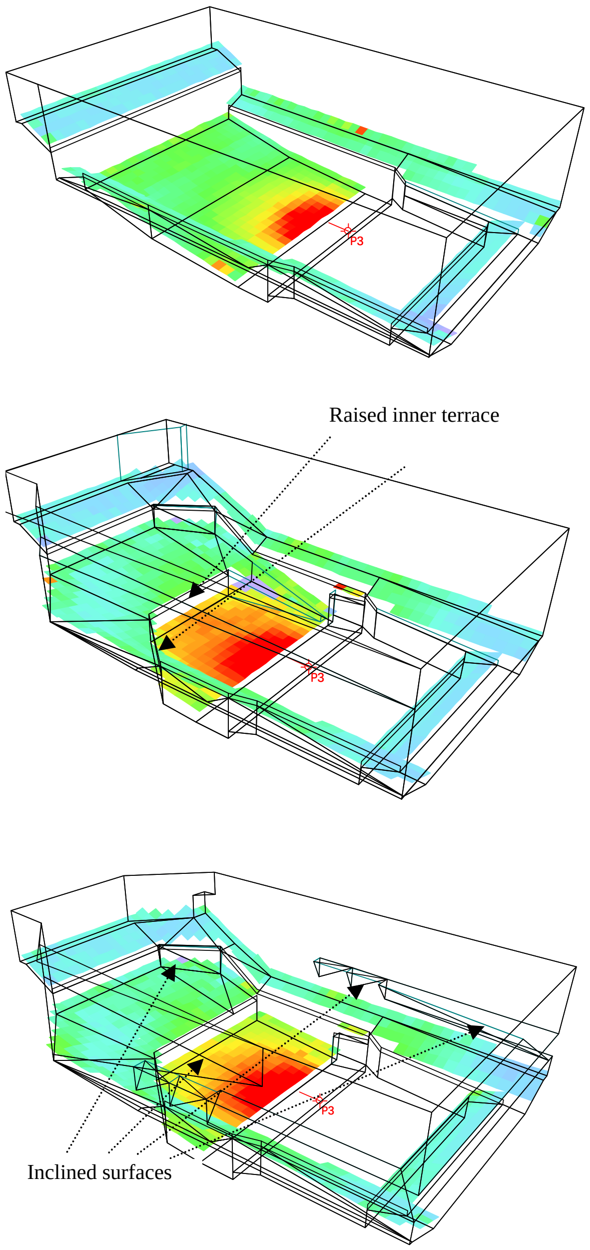

Figure 4. Distribution of 2-kHz band strength from a voice source comparing a rectangular configuration (top) to the configuration (middle) with raised inner terrace and the configuration (bottom) with raised inner terrace and inclined upper terraces and upper walls.

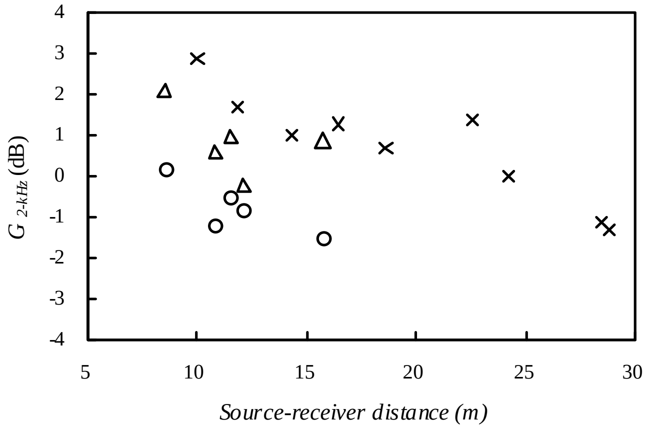

Figure 5. Simulated 2-k Hz band strength from a voice source as a function of source-receiver distance comparing the frontal seats (╳) in a rectangular configuration to the surrounding seats in the rectangular configuration (◯) and the optimized configuration with terrace seating (△).

With plane perimeter walls in the rectangular configuration, average 2-kHz strength G surrounding seats was approximately 3dB less than the value of frontal seats with the same source-receiver distance (figure 5). The difference was decreased approximately to 1.5dB for the optimized configuration with terrace seating. This agreed with the findings by Chiang *et al* using a directional source.

SUMMARY

This research was carried out to analyze acoustical design of a mid size concert hall incooperating staggered terrace seating in a hall with asymmetrical floor plan. Conceptual development and optimization process were both discussed regarding multi-dimensional criteria based on computer simulations. The major findings are:

1. An initial scheme containing the proportion of the Concertgebouw, Amsterdam was proposed where two major terraces were staggered. Preliminary simulation showed that lateral energy fraction was significantly improved throughout all seats.

2. Alternative schemes were developed following the similar concept but with the room width slightly reduced. The inner terrace was controlled around 12 m to 13 m away from the stage front line in order to direct early energy back to the players and to the surrounding seats. An outer loop of terraces was introduced where both sides of the rear walls were splayed. An optimization process was performed to fine tune the height of the terraces and inclination of walls. Simulations of models progressively changed from a rectangular configuration to an optimized terrace configuration showed that the high frequency strength from a vocal source can be increased by around 1.5 dB to improve the perceived timbre.

3. The reflection path originally existed in a rectangular form would be blocked by lower terraces on the side, as pointed out by Chen. It is, therefore, necessary to fine tune the reflective surfaces successively from the ones near the stage to the remote, upper surfaces. It is also important to note that adjustment of wall inclining, wall splaying, terrace height should be made with cautions in order maintain good balance among various parameters.

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