AN ACOUSTIC INVESTIGATION INTO THE ERASMUS HUIS AUDITORIUM IN JAKARTA

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Abstract

In architectural acoustics, small auditoria with less than 500 audience is usually give intimate acoustic characteristics. In the case of Jakarta - Indonesia, there are only a few auditoria have proper acoustic condition. One of the auditoria which is judged subjectively to have good acoustic quality is the Erasmus Huis Auditorium.

The capacity of the auditorium is for 300 people, generally used as multi-purpose performances. Good acoustic attribute judged to the auditorium should be assessed and evaluated, by investigating the behaviour of sound in the auditorium and in 1:50 scale model.

This paper evaluates the acoustic properties of the auditorium in relation with its interior design and shape. An optical measurement technique was employed using 1:50 scale model and a single laser beam as a source, to investigate the distribution paths of reflections, as well as acoustics measurements.

The results obtained from the measurements indicated that the design is excellent as a multi-purpose auditorium from both the architectural and the acoustical points of view.

1. Introduction

"Good acoustics" in an auditorium is characterized by many objective and subjective factors in which are correlated and are greatly influenced by architectural design factors, such as the enclosing structures and their characteristics. Thus the overall aural and visual design of an enclosed space has to satisfy both acoustical and architectural requirements.

The objective factors are defined by acoustic parameters and most well known theory is Sabine's reverberation time. On the other hand, subjective factors are mainly related to individual perception such as intimacy and spaciousness, introduced by Beranek. The architectural design factors of obvious importance are: size, plan form or shape, and effect of the boundaries whether absorptive or reflective.

Many aspects of the acoustic behaviour of spaces cannot be predicted accurately from the architectural drawings alone. To achieve a reliable prediction, a model of the auditorium can be constructed for further investigations. Two test techniques were employed: acoustic and optical. The first was used for evaluating the reverberation time and impulse responses in different seating area. The optical technique was employed for analyzing the distribution of sound reflections in a visual mode by using infra-red ray as the sound source.

2. Criteria in Auditoria Acoustics

1.1. Acoustic Criteria

Criteria in auditoria acoustics have been defined and established to indicate "good acoustics" in modern room acoustics. In this study, the objective acoustic parameters used for testing the model are: RT (Reverberation Time) and impulse responses.

RT (Reverberation Time)

Modern room acoustics has started with the reverberation time formula by W.C. Sabine in the 19th century [reprinted 1964]. Until now, RT has been considered as the most important criterion for auditoria acoustics. The auditorium volume (V), its audience capacity and attendance, and the enclosed surfaces whether absorptive or reflective (A), all contribute to influencing the RT of the auditorium. The Sabine's equation is defined in seconds as:

$$ RT = \frac{0.161 \ V}{A} $$

When the frequency is over 1000 KHz, the effect of
air absorption is significant and the equation can be rewritten as follows, where \((m)\) is the air absorption coefficient usually used in room acoustics.

\[
RT = \frac{0.161 V}{A + 4m V}
\]

Impulse Response

The impulse response is a measure of the response of an enclosure to an impulsive source that is dependent on time. The response is composed of numerous single impulses, starting with direct sound, followed by strong early reflections, the continuing with discrete and separate reflections from various surfaces within auditorium. The impulse response is useful for indicating the presence of disturbing echoes within the auditorium. The response is dependent on the interior design of the auditorium, and in particular the configuration and the finishing materials.

2.2. Architectural Criteria

The importance of architectural design factors are: size, plan form or shape, and effects of boundaries, whether absorptive or reflective. The size is defined from maximum audience capacity, and the surrounding walls and ceiling determine the shape of the auditorium, and the boundaries give specific acoustic characteristics.

Fan shape or its modification is commonly used for theatrical performances, due to the advantage of more members of the audience can be positioned at an optimum distance from the stage, which is better for vision and clarity of sound [Lord]. However, fan shape lacks of good lateral reflections, which is an important criterion for musical performances. The side walls provide few lateral reflections with poor conditions in the centre [Kutruff]. This disadvantage may be overcome by giving a modification of the shape, such as: elongated-hexagonal, octagonal, reversed-fan, etc.

3. Design of Erasmus Huis Auditorium

The 300-seat auditorium is located within the Netherland Embassy complex, as a part of the Erasmus Huis building. The performance of chamber orchestra music was the starting point in its acoustic design, but the auditorium is suitable for multi-purpose activities such as: popular music, recital music, conferences, lectures, plays, etc. In order to cater variety of performances, a semi-open stage design is adopted, as well as an electro-acoustic system is installed that enables the auditorium to be multi-purposed. The RT was designed 1.5 sec in mid-frequency for the empty auditorium.

The plan and shape: the Erasmus Huis auditorium has an octagonal plan, which is a modification of double fan-shaped plan. It is situated in the second floor of the building, surrounded by preparation room, meeting room, service, and lobby. These functions perform as a buffer to the auditorium from outside activities. These plan is judged to be better than a fan-shaped design, as poor of early lateral reflection in centre seating area can be overcome by the side walls of the octagonal shape. The auditorium is provided with enough surfaces in the seating area to ensure early lateral reflections. These surfaces are the walls of the boundaries. The surrounding walls are generally double-wall in order to avoid noise from outside of the building being transmitted into the auditorium. The major wall surfaces are modelled to avoid monotonous large surfaces and to prevent flutter echoes.

The main structure is made of concrete, and cavity brick walls are used to insulate the hall from intrusive noise. This heavy construction design is appropriate in avoiding noise from the outside of the building being transmitted into the auditorium.

The ceiling: to achieve optimum distribution of reflections, the ceiling is configured appropriately to the directed distributions. The finished material of the ceiling consists of: multiplex, rubber and vinyl layers. These materials are quite useful for energy insulation. Besides, the rubber seal provided is to protect the ceiling from vibration that may be occurred in the steel structure of the roof.

Stage: the stage is designed as a semi-open plan. The height is +90 cm from the floor level of front seating area, connected through wooden staircases. The distance between the front stage and the front seat is 3 m. The surrounding wall behind the stage is covered by thick curtain. The stage floor is finished with parquette strips over an air space. This design is desirable for the sound of cellos and double basses to radiate from the stage.

The seating area: the seating design feature is to locate the audience in front of the stage. The seating is portable, not fixed, they are made from a combination of light metal frame and upholstered
with selected porous fabric. This arrangement is proposed to achieve similar absorption when the auditorium is nearly empty with small audience as when it is fully occupied. The seats are designed without arms with a total width of 60 cm each. A control room is located behind the seating, equipped with a film projector.

A continental pattern of aisles in the seating area is provided. The advantage of this arrangements that spectators in the centre of each group could have unobstructed sight-lines. The back-to-back distance between rows of seats is designed 90 cm with 120 cm width of gangway, for comfortable and sufficient row spacing. The seating is raked to maintain satisfactory vertical sight-lines for the audience, and to avoid sound attenuation due to the grazing incidence effect. A gradient of 12.5° is employed for the seating.

Finishes : the main surrounding walls are finished with plaster, textured and painted, to ensure diffused reflections being produced over the seating area. The rear-side walls of auditorium are covered with colourful carpet to absorb unwanted sound and to provide aesthetic vision. This arrangement is also useful to provide the auditorium with absorption surface in order to reduce and adjust the exceeding RT. The concrete floor area is mainly covered with 6 mm thick carpet to provide impact noise reduction during performances. Besides, the floor of front area is made of parquette, this is done in order to produce reverberant effects from the early reflections.

4. Optical Measurements

The method adopted for investigating the uniformity of reflection coverage involved the study of dead-spots, loud-spots and early lateral reflections. A single laser beam was used to stimulate a sound source in the model. For easy adjustment, the light source was reflected by adjustable mirror reflector, with 3 cm height above the stage level to correspond human speaker.

The point of interest in the model (internal or enclosure walls within the seating area) and the ceiling were covered with mirrors and aluminium paper. To simulate a receiver, a piece of aluminium-coated paper was placed in the seating area at audience head level. The model was then filled with smoke, to make the distribution of reflections visible. Measurements were taken for each surface including edges, to assess their contributions of reflections over the seating area. Since only the first and second orders of reflections were of interest, the rest could be neglected.

The problem encountered during the tests is the 2 mm thickness of mirror that corresponds to 10 cm in the real scale. Dispersion might occur in the model due to the possibility of surfaces not being perfect, especially at the corners. Therefore, the positions most affected by reflections could not be determined exactly, although the approximated positions were visible. Besides, the measured reflections are independent of the time delay, therefore the delay is neglected due to perfect accuracy is not required.

5. Physical Model Used for Measurements

The basic material of model was plywood, it is suitable for modelling the massive structure of real enclosure walls, which are generally reflective. All exposed interior surfaces of the models were given three coats of smooth gloss varnish, to reduce the absorption coefficient of untreated timber at ultrasonic frequencies [Barron].

The seating is the principal absorbent in an auditorium. Thus, the absorption coefficient (\(\alpha\)) of the fabric used for the model seating had to be matched with that of the fabric used in real seating. The seating of the model was made from steel angled on timber strips, upholstered with a selected porous fabric. To determine the \(\alpha\) of the model seating, they were tested in a reverberation tank model [Legoh].

The source instrumentation used for the model is a spark source, it was set in the model at +30 mm height above the stage floor (+1.50 m real scale), corresponding to a human speaker’s height on the stage. The receiver is a 1/8” B&K microphone, the height was set +25 mm above the floor (+1.25 m real scale), corresponding to the height of audience ears in a sitting position. All source and receiver positions were used for the comparison in the frequency bands of 125 – 1000 KHz. The method used for acoustic tests was adopted from Legoh [1988], using air absorption reduction.

6. Evaluation of Acoustic Characteristics

Good correlation was obtained between calculated RT values and measured values with all source – receiver positions. The measured mid-frequency RT when the auditorium is empty is 1.3 sec, compared with the calculated RT of 1.05 sec. However, at low frequency the calculated RT values (1.13 sec) were a
bit shorter than the measured values (1.5 sec). It must be admitted that the calculated RT values is not a critical parameter, it is only a prediction and used as a reference to the measured values. Moreover, the absorption coefficient of materials could not be estimated precisely as well as the degree of diffusion.

For good acoustic quality, it requires that there be five or more reflections within the 80 ms after the arrival of the direct sound in the impulse responses. The measurements in the model showed that a good response is obtained at all measurement positions. In certain seat positions, especially in the front and middle seats, the early reflections were very strong. Also, when the patterns were analysed, it was concluded that there are no significant late reflections that might be heard as echoes. This was confirmed by the subjective tests.

From impulse response patterns, the energy reflections that create a sense of intimacy and speech intelligibility in the auditorium can be analysed. Since the limit of perceptibility is known for music 80 ms and speech 50 ms, the prediction is based on these two values. It was assumed that if these criteria are satisfied, the auditorium would provide clear speech intelligibility and a sense of intimacy. No significant loud or dead spots were indicated by the optical tests. It was assumed that the surrounding walls within the auditorium are dominant in producing valuable reflections.

Various performances were investigated in the auditorium, ranging from chamber music to a full orchestral concert. The auditorium is not satisfactory for full orchestra due to the music is unpleasantly loud. This is because of the hard and massive surfaces have little ability to absorb sound. On the other hand, when chamber music was played, the overall acoustic impression is very good. The clarity, intimacy and loudness are well balanced, and the music can be heard from all parts of the seating area.

Speech is also clearly heard from all parts of the seating area, it can be confirmed that no serious acoustic problems are encountered in the auditorium. The best seating position is in the middle, since direct sound has been enriched with early reflections, whereas the weak position is on sides.

All the results derived from the acoustic and optical tests are in agreement, although the optical tests are independent of time. The overall acoustic quality of the auditorium can only be determined and judged by examining and comparing them in combination.

7. Summary

It was interesting to observe the acoustic characteristics of the Erasmus Huis design. Obviously, the materials chosen as well as the design of shapes of the enclosures are important factors affecting the acoustic quality of an auditorium. The absorption coefficient of the enclosure materials, the shape of the surrounding walls, the ceiling configuration, and the seating arrangement, create the specific acoustic character of the auditorium. In the auditorium design, therefore, architectural and acoustical factors should be carefully determined and be properly balanced.

From the results, it was found that small auditorium produced good acoustics. The Erasmus Huis have good acoustics even without significant and special acoustic treatments, only by providing carefully selected architectural and acoustical design factors. The acoustic parameters were more acceptable, uniform, and easy to be treated in small auditorium with 300 audience. No serious acoustic problems encountered during the investigations.

Beranek stated that there is no "ideal acoustics" since each successful auditorium displays its own unique sound and acoustical character. Re-arranging the shape and interior is the most practical and efficient way to adjust the acoustics of an auditorium as desired. It is hoped that these results are useful to define the auditoria conditions that are expected to produce "good acoustics".

8. References

4. LEGOH, F. (1988); Acoustic Design and Scale Model Testing of A Multi-purpose Auditorium; MSc Thesis of the University of Salford.