SIR HAROLD MARSHALL – A TRIBUTE TO AN EXCEPTIONAL AUDITORIUM DESIGNER

Mike Barron Retired. m.barron@btinternet.com

1 INTRODUCTION

Sir Harold Marshall was born in New Zealand in 1931 and died in 2024 at the age of 92. His reputation rests principally on a series of remarkably impressive auditoria. His undergraduate training was a joint study in both architecture and physics over 6 years, which no doubt provided an excellent foundation.

Prior to his acoustic design phase however, he was originator of the idea that lateral reflections within the early sound were valuable for music listening. This has been very influential for subsequent concert hall design.

The following two events and six significant auditoria will be considered below:

2. Judging the architectural competition for Christchurch Town Hall (1966)
3. Spatial responsiveness/ spatial impression (1967)
4. Perth Concert Hall, Western Australia (1973)
5. Christchurch Town Hall, New Zealand (1972)
6. Michael Fowler Centre, Wellington, New Zealand (1983)
7. Segerstrom Hall, Orange County, California, USA (1986)
8. Guangzhou Opera House, China (2011)
9. Philharmonie de Paris, France (2015)

A valuable source of information suitable for this account is the autobiography by Marshall "Korowai of life and love", published privately [1]. Three of the above halls (nos. 5-7 above) were measured by this author and reported in his book "Auditorium acoustics and architectural design" [2].

2 JUDGING THE ARCHITECTURAL COMPETITION FOR CHRISTCHURCH TOWN HALL (1966)

An architectural competition was being held for a new concert hall for the city of Christchurch on the South Island of New Zealand. It was/is known as Christchurch Town Hall. It holds an audience of 2340. At the time, Marshall was at the Institute of Sound and Vibration Research (ISVR) at Southampton University, UK.

It is 1966, imagine you have received the five entries and have to comment on their acoustic suitability. What criteria are you going to apply?

You start with the only accepted objective measure for rooms, the Sabine formula. This tells you the volume required for your auditorium but says nothing about the form/shape of your hall.

However in 1962, Beranek had published “Music, acoustics and architecture” [3], which potentially claimed to have the answers. It was based on a survey of world concert halls. The survey demonstrated that the form of a hall IS significant, with parallel-sided halls considered to have the best acoustics. (Ironically these halls were mostly built in the 19th century. Architects conforming to the Modern Movement rejected such examples from the past. Their concert halls tended to have inferior acoustics!)

Beranek’s new proposed measure was the **Initial-time-delay-gap, ITDG**, the delay of the first reflection in ms. However in 1962 the Philharmonic Hall, New York had opened guided by this new parameter and been severely criticised for its acoustics. None of the competition entries for Christchurch was parallel-sided, so what to do?

Harold Marshall decided to attend a concert in the London Royal Festival Hall (of 1951) to “refresh his ears”. Listening attentively due to his current task, he noted: “I realized that there was only frontal sound at my position - the lateral reverberation was inaudible” [1]. He later associated this with the significant width of the RFH (32m). Soon after, he experienced a concert at the Concertgebouw, Amsterdam, and witnessed the positive effect of lateral reflections. Following research into published subjective experiments in Germany, Marshall concluded that the effect was linked to unmasked early lateral reflections.

Of the five competition entries, Marshall proposed the design by architects Warren and Mahoney as the most promising in terms of acoustic performance. In mid-1967, Marshall left the UK and took up a post at the University of Western Australia, Perth.

3 SPATIAL RESPONSIVENESS/ SPATIAL IMPRESSION (1967)

It was at this point that the acoustician from New Zealand entered my life, but not in person. In 1967 I applied to ISVR at Southampton University and was told that they had already bought the crucial piece of equipment (a tape delay machine) to test this lateral reflection theory. It was almost as if ‘How soon can you start?’. Yet at this point I did not know any acoustics! After 2 years conducting research at Southampton, I joined Marshall in Perth, Western Australia. The study found that lateral reflections were valuable and that the magnitude of the effect, called Spatial Impression, was linked to a simple measurement performed on impulse responses recorded on microphones with omni- and figure-of-eight directivities: the early lateral energy fraction, ELEF [4].

Though it has been shown that spatial impression is a component of the best acoustics, what is its significance relative to the other desirable subjective characteristics, such as clarity? A discussion of three halls with seating areas with some high values of ELEF [5], demonstrates that the best acoustics also depend on optimum values for a series of objective measures (principally objective clarity, Early decay time and total sound level).

4 PERTH CONCERT HALL, WESTERN AUSTRALIA (1973)

Perth Concert Hall opened in 1973 with ~1700 seats. The principle users were to be the Australian Broadcasting Corporation orchestras, who specified a ‘shoe-box’ hall. They had their wish with a parallel-sided hall with two sets of boxes lining the side walls, higher at the rear. The upper line of boxes meets the choir seating at the stage end. The hall has established itself as having good acoustics. Marshall considered that the hall offered an insufficient challenge!

(Before we leave Western Australia, a charming anecdote: Marshall was asked to assist with a client in a village north of Perth. They had a corrugated iron shed that was used for showing films, but with serious acoustic problems. The obvious solution was to add sound absorbing treatment, but the client had no money! Marshall proposed egg boxes, which could be obtained free from the local Egg

Marketing Board; the client just had to collect them. After a few weeks, the egg boxes had still not been collected. When contacted, the client explained that: “The egg boxes are too difficult. Please suggest an ‘acoustic paint’”!)

5 CHRISTCHURCH TOWN HALL, NEW ZEALAND (1972)

The acoustic design of the Christchurch Town Hall certainly did present a challenge. The plan shape is basically elliptical with a balcony running round the full perimeter. The walls consist of 14 vertical planes. A series of approaches were used to control the focussing caused by what are effectively concave surfaces. At stalls level below the balcony, the seating is raked towards the perimeter, while the soffit descends towards the rear, leaving only a limited section of the vertical wall exposed (Figure 1). Above the balcony, large plane reflectors provide early reflections not to seating in front of the reflector but to the **adjacent** seating block. Towards to the rear of the hall, dihedral (two plane surfaces) reflectors were found necessary. The seat capacity is 2340 plus 324 choir, yet the furthest seat is only 28m from the front of the stage. The ceiling height is a generous 21m.

The principal subjective characteristic of the sound in the Town Hall is not so much that of lateral sound, though that certainly exists, but an intimacy and identification with the performance. This allows listening to individual musical lines, yet there is a rich sense of reverberation. Inspection of the objective characteristics helps provide an explanation for this [2, Appendix C.1]. In the unoccupied condition, the reverberation time (RT, 500/1000Hz) is 2.6s, whereas the EDT is 2.1s, giving a ratio of 0.81. The predicted occupied RT is 1.92s, within the normal acceptable range. The physical reason for this behaviour is very probably the subdivision of the space vertically. The reflectors direct sound onto sound absorbing seating/audience, while reverberation comes from the volume above. For this approach to work depends on a substantial basic reverberation time.

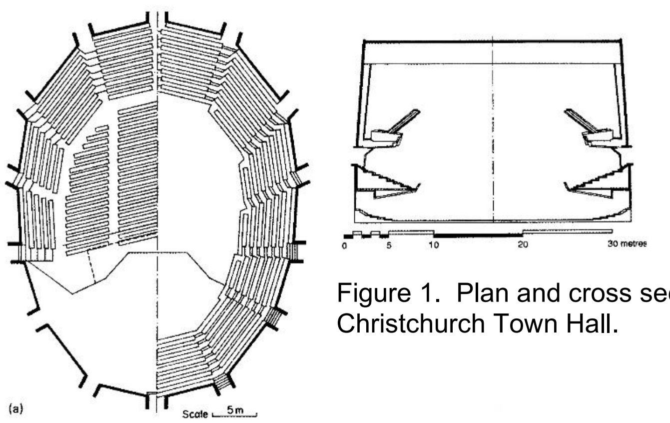

Figure 1. Plan and cross section of Christchurch Town Hall.

6 MICHAEL FOWLER CENTRE, WELLINGTON, NEW ZEALAND (1983)

The concert hall in the Michael Fowler Centre of 1983 clearly originates from the same stable as that in Christchurch. The hall has a capacity of 2570 including choir. The obvious difference is that instead of plane reflectors, slot diffusers were used as suggested by Schroeder [6]. These are Quadratic Residue Diffusers (QRDs), which have a predictable scattering pattern. They avoid two risks with reflections from plane surfaces: false localisation and tone colouration. The Michael Fowler Centre is the first occasion that slot diffusers were used in a concert hall.

There are two basic differences between the two New Zealand halls. Whereas in Christchurch the stalls floor is flat, it is raked in Wellington. Another difference is that reflectors in Christchurch provide reflections to seating blocks adjacent to the reflector, while in Wellington sound is reflected to the opposite side of the auditorium. There was concern that the diffusers would also exhibit back scattering; this was experienced in subjective tests in a 1:10 scale model of the hall. It was however considered to acceptable.

Objectively both halls have average EDTs much shorter than the RT; the ratio in Wellington is 83%. But the significant difference is that the unoccupied reverberation time is only 2.23s in Wellington. This leaves a predicted occupied EDT of 1.75s, slightly shorter than ideal. The likely cause of this is effective absorption by the diffusers, a characteristic not understood in 1983.

7 SEGERSTROM HALL, ORANGE COUNTY, CALIFORNIA, USA (1986)

The brief for Segerstrom Hall of 1986 was for a multi-purpose auditorium, based around a proscenium stage, with a demanding capacity of 2900 audience. To maximise the audience numbers within a distance limit, the optimum plan form is a fan-shape. This plan form however has a poor acoustic reputation, mainly due to the lack of early lateral reflections. Marshall produced a solution based on lateral thinking: imagine that an earthquake split the auditorium in two with one side dropping about 3m, Fig. 2. This creates an asymmetrical design; instead of one balcony level, there are four seating levels. The acoustic virtue of this scheme is to introduce vertical surfaces able to provide lateral reflections.

Another feature of the design is an extensive series of Quadratic Residue Diffusers on the side wall surfaces at the proscenium end, with the aim of providing additional early lateral reflections. The objective characteristics [2, Appendix C.2] are impressive: an occupied RT of 2.0s, a mean EDT also of 2.0s, indicating a diffuse sound field. Objective clarity and lateral fraction are close to preferred values. The total sound level (loudness) is close to predictions (by revised theory), even at the rear of the hall. This is testament to the virtue of high balcony overhangs. Several comments have been made by audience members that there must be electronic assistance at the rear of the hall; in reality there is none.

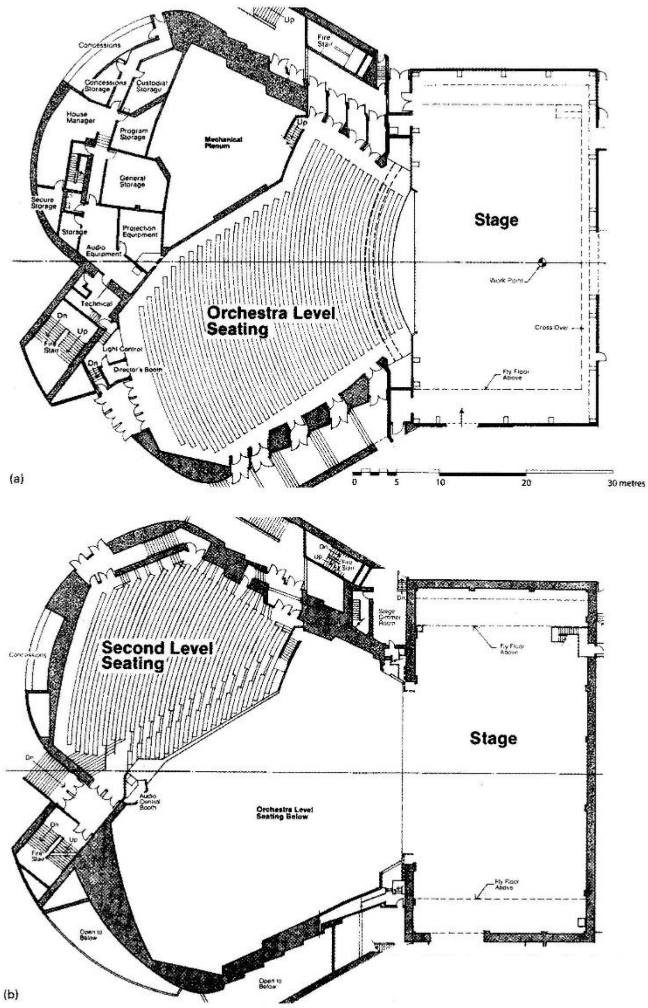

Figure 2. Plans of the 1st two levels of Segerstrom Hall.

8 GUANGZHOU OPERA HOUSE, CHINA (2011)

In Segerstrom Hall, there is obvious use of an asymmetrical design for acoustic reasons. This technique was likewise exploited for the Guangzhou Opera House, which also has a proscenium stage. The architect for the house was the late renowned Zaha Hadid; it has 1800 seats and opened in 2011. Marshall Day Acoustics contributed to the winning project of the design competition. Marshall quotes the aim as “a room in which sound and sight together contribute to the concert experience” [1, p.165].

A range of reverberation times are found in actual opera houses. There is an inherent conflict between the desire for the words to be comprehensible and a reverberant response from the room. This opera house is also used for orchestral concerts, using an orchestra shell behind the proscenium. For this use, a longer RT is preferred. An RT goal of 1.6s was chosen, but as with several Marshall designs a secondary aim was a high level of early reflections.

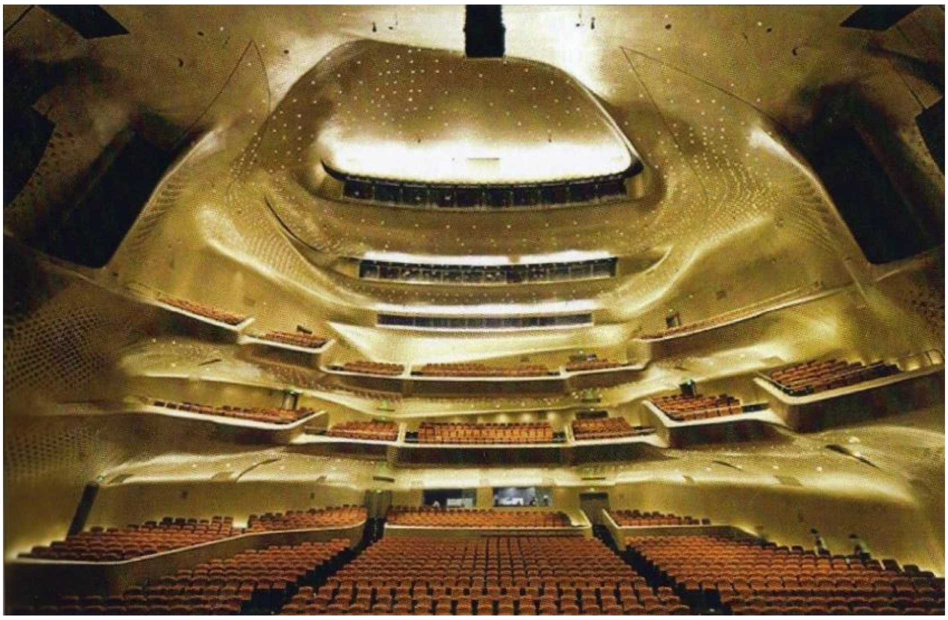

Figure 3. Rear view of the Guangzhou Opera House

A characteristic of this opera house is ‘flowing geometry’, with few actual edges. Above the stalls level, a series of terraces are used, with useful bounding surfaces for reflections. An Odeon computer model was constructed, but to represent all the curved surfaces, a total of 6250 plane surfaces were used. A physical scale model at 1:25 was also tested. Many design workshops were necessary to optimise behaviour, among other requirements being the avoidance of acoustic focussing. It was found necessary to have diffusing surfaces close to the proscenium opening.

The measured reverberation time occupied is 1.5s and the mean objective clarity (early-to-late sound index) is effectively +2.2dB, contributing to intelligible speech. The acoustics of the house have been widely praised.

9 PHILHARMONIE DE PARIS, FRANCE (2015)

The acoustic design for the competition for a new concert hall for Paris was based on an extensive brief developed by Eckhard Kahle. Marshall was invited to join the design team of the prominent French architect Jean Nouvel, which then won the competition.

The acoustic concept could be called "bicameral": the central enclosure contains the audience and is designed to supply suitable early reflections. The central enclosure is linked via openings to an outer space, which provides later reverberation. For the central enclosure balcony fronts, suspended reflectors (roughly horizontal, often called clouds) and surfaces at the rear of balcony sections were individually manipulated. The goal was for every seating area to be served with predominantly lateral reflections. The hall opened in 2015 with a total audience size of 2400.

The design was the product of a series of workshops, attended by representatives of the architect, acoustician and theatre consultant. The complexity of the design was such that it challenged current computer programs! A 1:10 scale model was also tested. The resulting acoustics have been enthusiastically greeted by the likes of the conductor Simon Rattle.

10 FINAL THOUGHTS

Harold Marshall was the most inventive acoustic designer of his generation. Almost by chance, he studied both physics and architecture at undergraduate level, which proved to be an ideal combination for an acoustic consultant of auditoria. Marshall brought his individual mind to projects, often employing lateral thinking to tackle new challenges.

Though the projects on which he advised were diverse, there is a certain consistency in the acoustic processes he followed. His early realization, that reflected sound arriving from the side was a component of the best acoustics for music listening, provided a major acoustic goal. To achieve this, he realised that asymmetrical design in plan can introduce valuable sound reflecting surfaces. And experience of his first major concert hall project demonstrated that clarity and reverberation need not be mutually exclusive, by combining surfaces to enhance early reflections with a large auditorium volume.

I count myself very fortunate to have known and worked with Harold Marshall throughout my working life. There are several of us here who might claim to be "members of his fan club". He was a courageous and highly original designer, whose life deserves celebration.

11 REFERENCES

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