ACOUSTIC UPGRADE FOR THE CONCERT HALL OF THE SYDNEY OPERA HOUSE

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1 INTRODUCTION

The Sydney Opera House is one of the most prominent buildings worldwide and a truly iconic place. Its planning and construction history is full of interesting and surprising details. After a much too short planning time for an extremely elegant but unbelievably demanding building shell, the construction work needed to be started to save the project from being terminated. At this time, the interior planning was far from being finished. With changes in the requirements for the planned venues, the situation got even more complex leading to a nearly unsolvable challenge for the architects and acousticians who took over the project after Jørn Utzon and the whole planning team, including Lothar Cremer as the leading acoustician, left the project in 1966.
The plan to have a large, combined hall for concert and opera was discarded. Instead, the volume under the shells which was planned to accommodate a drama theatre was rededicated to an opera venue, leaving the larger volume free to be a pure concert hall.
In this volume, the architect Peter Hall and the acoustician Wilhelm Jordan designed an impressive concert hall with 2,600 seats and a large stage surrounded by the audience. Using as much as possible of the volume that was created by the shape of the outer shells resulted in a very unique shape of this venue. The maximum height of the venue, 23 m, is directly above the stage. From a strongly structured and nearly horizontal ceiling above stage and lower stalls area, the ceiling follows the outer shells like a tent until it reaches a position above the audience boxes which surround stage and stalls area. A step in the ceiling at this position creates large vertical wall areas as well as horizontal ceilings above the boxes and the rear part of the circle audience area.
After 15 eventful years of planning and construction, the Sydney Opera House was inaugurated on 20 October 1973. In 2007, the UNESCO included it – as the newest building so far – in the World Heritage List.

Figure 1. Sydney Opera House.

2 RENEWAL PROCESS

Funded by the New South Wales Government, the Sydney Opera House started a comprehensive 10-year renewal program for the building and the large venues inside in 2012 intended to be completed for the 50th anniversary of the building in 2023. The works comprised creating a large new loading dock below the forecourt (and below sea level), upgrading acoustics, stage machinery and accessibility of the Joan Sutherland Theatre, which is the opera hall inside the Sydney Opera House, and culminated in the renovation of the Concert Hall.
Beside fundamental acoustic improvements, the aims for this part of the project have been to considerably shorten the changeover times between acoustic and amplified concerts and to provide new possibilities with a state-of-the-art stage machinery for large shows. Fulfilling modern accessibility requirements and upgrading large parts of the ventilation system were also included in this large-scale renovation.
The project planning for the Concert Hall started in 2015 shortly after the planning for the upgrade of the Joan Sutherland Theatre.

3 ACOUSTIC CHALLENGES

The acoustic challenges posed by the sheer size of the Concert Hall and its very special shape had been subject of intense discussions since its opening in 1973. They affect the audience as well as the orchestra on stage.
At first sight and considering the size of the venue and the occurring distances, the acoustic perception is quite satisfactory in many audience areas. A closer look reveals a couple of acoustic effects with a large potential for improvement.
For the main part of the audience in the stalls and the circle, the reverberation emanating from the large volume above stage and stalls with its vertical walls was quite prominent, adding a strong and unusually localizable perception of cloudy reverberance to the sound of the orchestra.
Seats in the circle with a large distance to the stage suffered from feeling disconnected from the stage since the perceived sound source distance was just matching the real distance. At the same time, the perception of dynamic changes in the music was not really supported by the acoustics of the venue.
In the stalls area, the flat side walls provided reflections which were strong enough to create a wrong localization of instruments on stage with hidden direct sound.
The orchestra on stage suffered from a lack of contact between the musicians as well as from a lack of perceived support for the own instrument. The acoustical contact between the orchestra and choir on the choir stalls behind the podium was challenging as was the acoustic perception among the choir singers. The building’s World Heritage status made the already quite demanding project even more challenging for all parties involved.

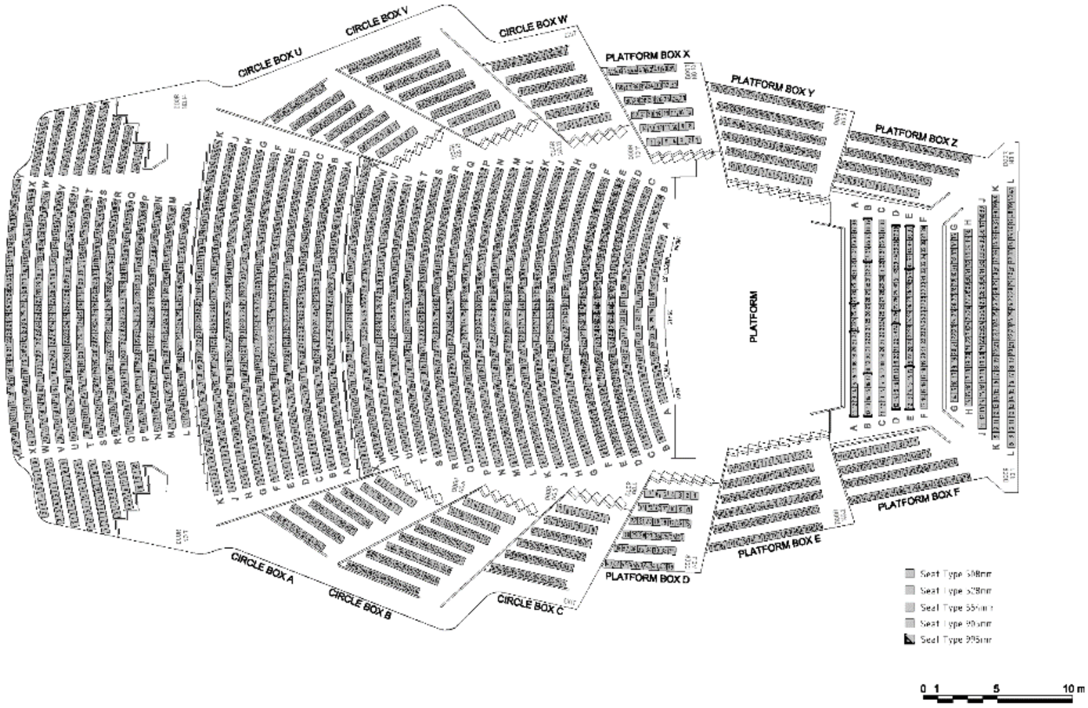

Figure 2. Floor plan of the Concert Hall.

4 DESIGN PROCESS

Identifying and classifying the acoustic challenges was a process including several different approaches. The most important part in this project is the subjective listening during concerts and rehearsals, switching between different seats and comparing acoustic perceptions for a range of concert programs, as well as interviews with the musicians and experienced concert goers.
A valuable support for this evaluation are simultaneous recordings which had been performed with 6 pseudo dummy heads with two additional rear channels. The playback of these recordings in an anechoic chamber with a suitable 4-channel loudspeaker setup with crosstalk barriers delivers the possibility to instantly switch between different seats during the music uncovering effects which otherwise are hidden by the deficiencies of the human acoustic memory.
Extensive acoustic measurements in the unoccupied as well as in the occupied hall provided additional input for the assessment of the situation.
To detect the influence of various sound sources on the overall background noise level, an absolute silence test was performed. Switching off all sources contributing to the background noise and measuring the occurring sound levels at different positions in the venue for each single sound source delivered valuable insight into the composition of the background noise and the potentials for reduction.
The design process itself was mainly based on a 3D computer model of the venue and various simulation tools. These tools provide the possibility to reproduce the results of the measurements and understand the performance of the existing situation. Changing geometries and rearranging the acoustic energy distribution and time structure help step by step to define and improve the suggested acoustic measures.
For very important questions or measures which cannot be computationally modelled with sufficient reliability, acoustic measurements of scale models or prototypes were used. This included tests of a new concept for the absorption above stage as well as the vibrational properties of the floor construction on top of the stage risers. In addition, material tests, for example of absorption banners or the audience seats, were performed in the laboratory to gain a reliable data basis.

5 ACOUSTIC MEASURES

The most prominent change with also the most decisive impact on the audience are the new reflectors above the stage. Replacing the smaller and very diffuse reflecting old donut-shaped acrylic reflectors, the new reflector arrangement above stage is able to control the acoustic energy in the reverberation volume above the stage. At the same time, the reflectors provide valuable support for the contact on stage, for the choir and as well as for the more distant parts of the audience resulting in a valuable decrease of the acoustically perceived distance.

Figure 3. Reflectors above stage.

Movable reflectors along the upper side walls are used to improve the contact on stage, support the projection of the choir and strengthen the response of the venue on dynamic changes of the music. Due to heritage requirements, these reflectors needed to totally disappear when not deployed. The space and structure behind the surfaces in this wall area required an engineering masterpiece to make this possible.
Lowering the stage from 1.3 m to now 0.9 m and using arena style automatic risers for the orchestra aimed at supporting the contact on stage and improving the orchestra balance in the stalls area.
The thereby enlarged walls around the stage as well as the sidewalls of the stalls area got a diffusely reflective, wave-shaped surface structure milled from massive timber. Similar surfaces with smaller wave amplitude are supplied at the rear wall of the boxes around the stage, replacing fabric areas, and in the circle.
Changing the horizontal angles of the sidewalls of the rear stalls area was a measure to provide a more homogeneous sound energy distribution with these very important reflection areas.

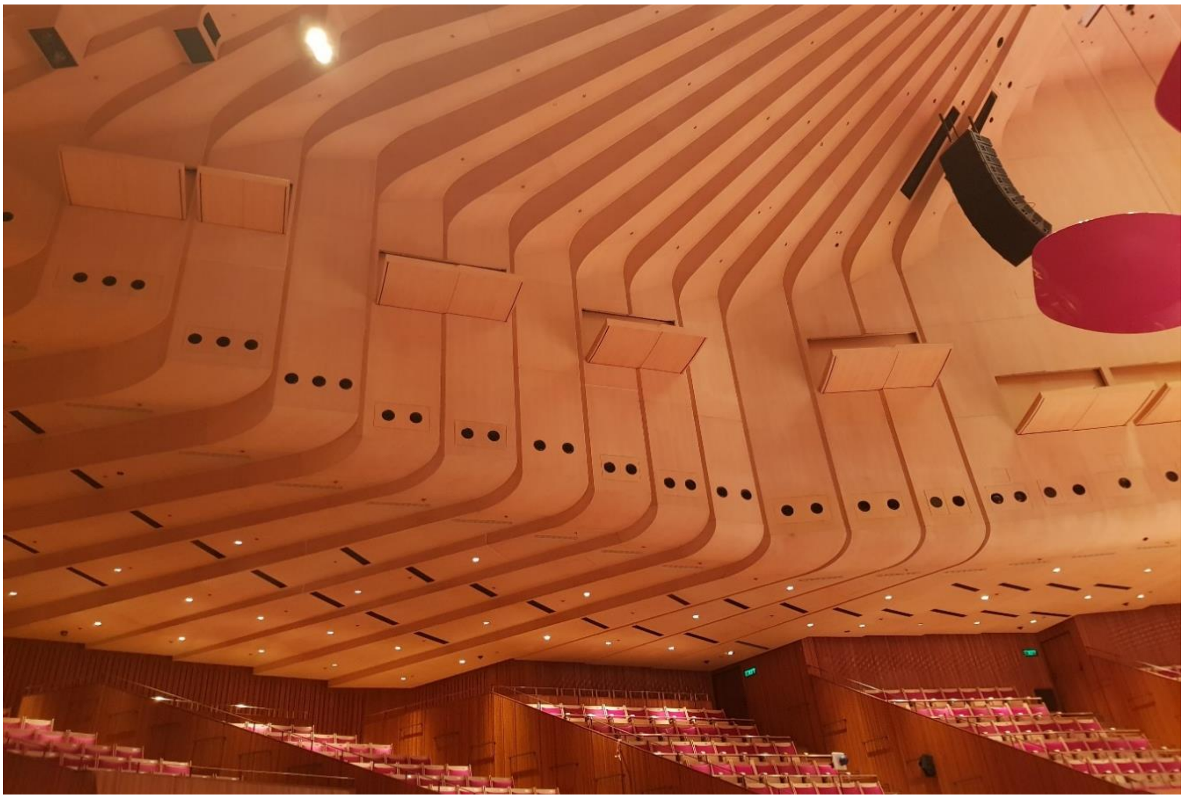

Figure 4. Deployed side wall reflectors.

Figure 5. Structured wall surfaces.

Before renovation, an absorbent canopy above stage had to be manually deployed when using the venue for amplified concerts or shows to avoid filling the huge volume above stage with reverberant sound energy. As an automated replacement of this time-consuming procedure fabric banners in two ring structures are deployed from the ceiling. The reflector elements are moved above the bottom of the banners and tilted so that sound from stage is redirected into the absorbent banner areas. This very effective dampening of the volume above stage is supplemented by automated fabric banners along the side walls and behind the boxes. Together with the newly designed sound system this provides much better possibilities for the sound design of all kinds of reinforced performances. The fundamental decrease of the necessary time for changeover between the acoustic and the amplified mode of the venue creates totally new possibilities for the booking of the venue.

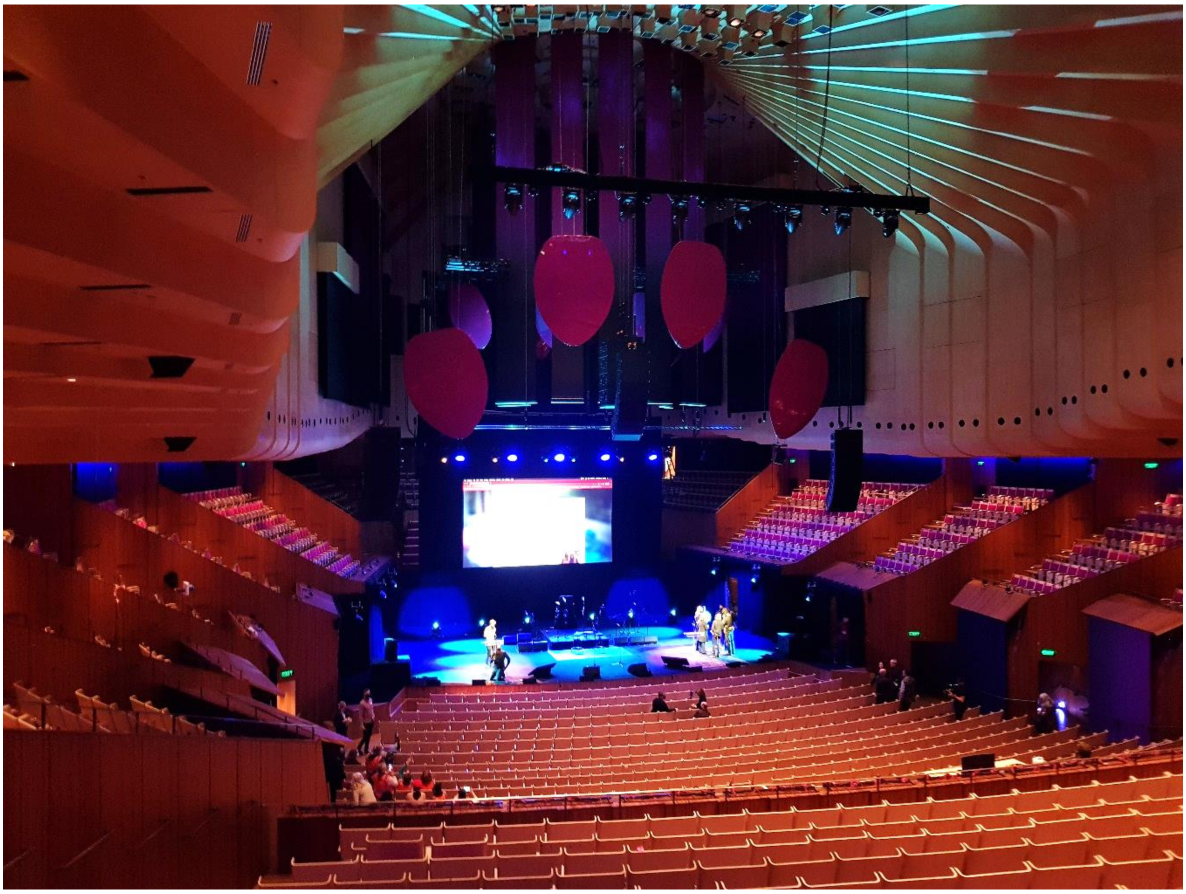

Figure 6. Amplified mode.

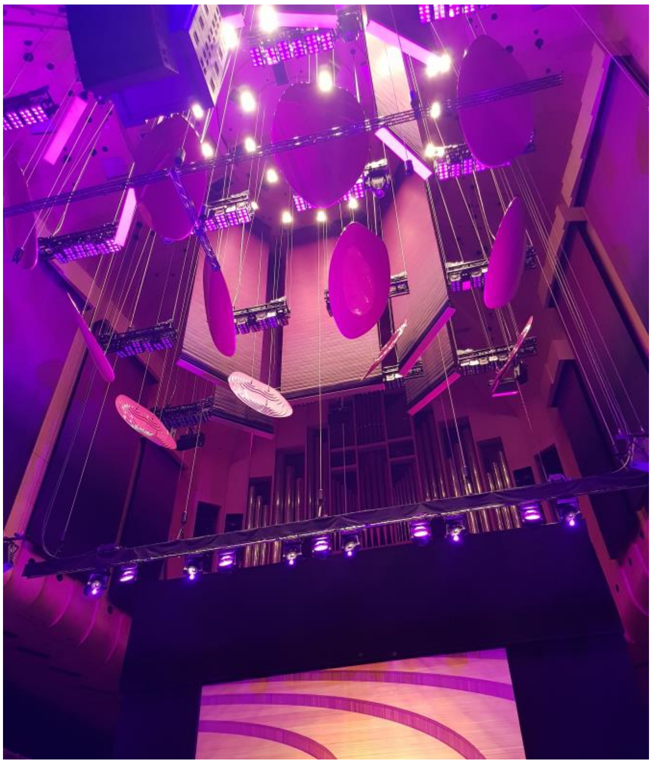

Figure 7. Reflectors above stage in amplified mode.

Moving and tilting the reflectors above stage in between the lighting pods and absorbent banners required a breathtaking precision of the stage machinery which makes it understandable that the executed solution was unimaginable about 50 years earlier.

6 ACOUSTIC PROTOTYPE TESTING

To ensure the efficiency of the proposed measures and to collect input for further refinement, two blocks of in-situ testing were performed. During 10-day periods of rehearsals and performances of the Sydney Symphony Orchestra with added special rehearsals of the Sydney Philharmonic Choir and the Australian Chamber Orchestra, the new stage layout as well as the planned reflector layout were tested in the Concert Hall before being included in the construction program.
A similar test setup was used to assess and improve the absorption with the banner rings above stage in the amplified mode of the venue.


Figure 8. Riser testing 2016 – with the so-called donut reflectors above the podium.

7 CONSTRUCTION PHASE

The Concert Hall closed in 2020 for extensive construction works. Due to the Covid pandemic, the already quite complex construction site became even more challenging with delays in the supply chain and travel restrictions for all the specialists.

A huge part of the project constituted the very complex structural works which were necessary to lower the stage level and rearrange the whole area above the ceiling of the venue. These works also included a complex structural decoupling of the stage slab to at least restore the sound insulation of the previous construction. In the ceiling void above stage, a new air handling unit needed to be integrated together with a highly sophisticated new winch system, and to be acoustically insulated from the venue directly below.

On the other hand, very precise and fine scale work had to be accomplished to ensure the vibrational properties of the stage floor. The combined requirements of load, heritage and acoustics led to a construction where the timber floor is floating and resonating for orchestra loads as well as providing rigid support for higher loads.

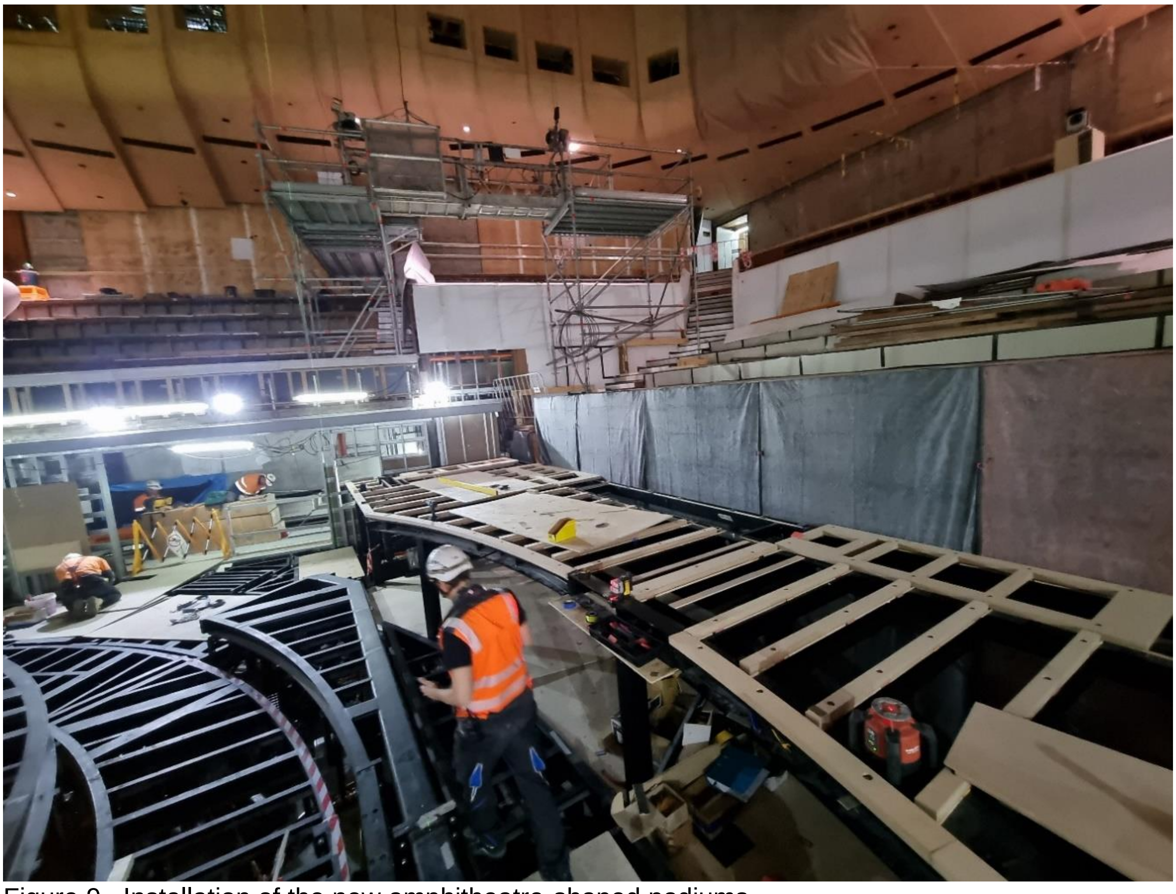

Figure 9. Installation of the new amphitheatre-shaped podiums.

8 COMMISSIONING

The construction phase was finished in June 2022 with handing over the building to the artists again. In addition to extensive acoustic measurements, the commissioning phase also included several test rehearsals to gain some experience with the acoustic measures and to support the orchestra in getting familiar with the new situation. Beside optimizing the variable measures like reflector height and inclination, experimenting with the orchestra seating was an important part of this acclimatization phase.

Figure 10. Inauguration with a gala concert.

On 21 July 2022, the upgraded Concert Hall was reopened again with a gala concert of the Sydney Symphony Orchestra. Looking at the very positive feedback from musicians, press reviewers and the community the acoustic measures reached their goal: Providing acoustic conditions in the Concert Hall that keep up with the visual majesty of this architectural master word.

9 REFERENCES

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