Acoustics in gesamtkunstwerk; design of the Phoenix Central Park Performance Space

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ABSTRACT

The recently opened Phoenix Central Park is a building space dedicated to art, performance, nature and culture. The result of an open architectural brief based around the German concept of gesamtkunstwerk, broadly translating to, a total artwork. At the heart of the building is an intimate performance space, with a folded bell shaped internal form. The space does not have a stage or traditional seating, but instead invites artists to perform anywhere and audiences to likewise find their own place to experience the performance. The first acoustic challenge was to determine what the space should sound like, with an open brief and few boundaries of how the space would be used. The design challenges increased as the form of the space evolved with complex geometries and the need for a coherent singular expression and with acoustic treatment not perceived as a separate element. . The finishes presented unique challenges, initially including gilded/gold leaf acoustic panels but ultimately evolving into a singular bell shaped room constructed with stepped and contoured free-formed cross laminated (CLT) components incorporating tuned acoustic resonators. The Phoenix opened in 2020 and has been well received by audiences and critics alike.

1 INTRODUCTION

The Phoenix Central Park, Chippendale NSW is a private development conceived by philanthropist Judith Neilson. The development comprises two distinct 'wings', separated by a central courtyard. The eastern wing of the development forms an art gallery space, with architects John Wardle Architects (JWA) responsible for the design of this wing. The western wing includes a performance space, with architects Durbach Block Jaggers (DBJ) responsible for the design here. The original design included a residence for visiting artists above the performance space, however this was revised to use for administrative space during later design stages. A carpark is located underneath the building.

The project was conceived as a Gesamtkunstwerk, a German word translated as "total artwork". Judith Neilson "envisioned a space in which architecture and interior design as well as the visual and performing arts would each enhance and embrace the other for an immersive total experience - a 'gesamtkunstwerk', or 'total work of art'" (Judith Neilson Projects, n.d.).

This paper focuses on the acoustic design of the main performance space, although many areas including the carpark, gallery, stairwells, rooftop terrace and elevator have all been used as performance spaces.

2 DESIGN BRIEF

Many of the normal parameters used to derive acoustic targets did not have clear definition for the space. There was no fixed seating, other than a bench seat around the periphery of the ground level and no defined audience area. As a result, traditonal acoustic parameters defined by the venue capacity were not able to be precisely determined. There was no stage area, or single point from which performance would occur, so a traditional reflection sequence design around a performer to audience location was not possible. The type of program material was not defined but could include many sources including speech and unamplified music. Potential uses also included amplified music or performance art but the original design did not include any in-house sound system (although provision was made for this later). The performance space was not separated from other parts of the building by partitions and doors in the way a traditional theatre would be. No precedent venue was nominated by the stakeholders as being comparable.

The client direction was to create a "perfect acoustic cave". An acoustic return brief was prepared drawing together a subjective and quantitative response to the open form of the stakeholder directions.

It was recognised at the time the return acoustic brief was prepared that the strong architectural elements in the performance space may drive the acoustic outcomes of the space and as such acoustic finishes in the room may not comprise conventional exposed elements when compared to a more traditional design approach. The return brief also acknowledged that the direct exposure of the performance space to other areas within the building would limit the acoustic separation that was achievable. An expectation was set in the return brief that stakeholders, performers and patrons would need to modify their expectations and behaviour to suit the nature of the building.

3 DESIGN TARGETS

A reverberation time target in the range of 1.2 to 1.5 seconds was determined based on the need to balance speech intelligibility in the space with the need to provide a full sound for acoustic music performances. Guidance was taken from a range of subjective perception curves and experience including those from (Burd et al, BBC 1966), based on the room volume. While the audience location and capacity were not able to be clearly defined an initial target was set based primarily on the room volume of approximately 1640m^3, together with a nominal allowance for 50 people in the space and use with unamplified speech and music. The spectral target limits for reverberation time are described in Figure 1 and Table 1, where T_m is the average reverberation time by which the remaining tollerances are expressed relative to (Walker, 2002).

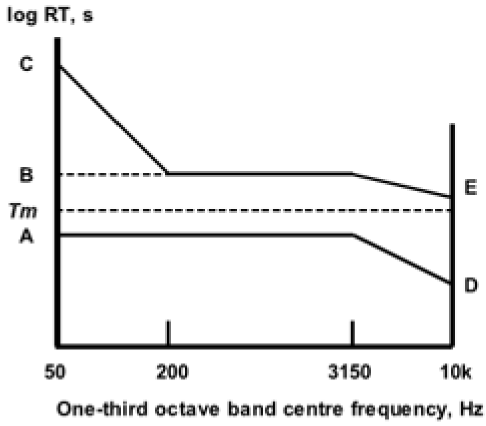

Figure 1: Reverberation time tolerances (Walker, 2002)

Table 1: Reverberation time target for Performance Space

Space	Volume	T_m	Tolerances				
	m^3	(s)	A	B	C	D	E
Performance Space	1640m^3	1.35	1.1	1.6	2.1	1.0	1.2

It was critical that the Performance Space be free from audible anomalies such as discrete room modes or flutter echoes as a result of room dimensions or intrusions into the space such that formed by the balcony.

4 PRELIMINARY DESIGN STEPS

Initial calculations indicated that the performance space would require 320m^2 equivalent absorption area across a broad range of frequencies in order to achieve the reverberation targets.

The architectural design concept was a folded bell shape, with no delineation between the 'walls' and 'ceiling'. An initial ray tracing analysis was performed on the preliminary room shape to review the likelihood of problematic reflections within the space. Two main source locations were examined for the ray tracing, being on lower floor as well as on the upper balcony. Without acoustic treatment, the concave areas of the feature roof were shown to cause localised focussing of sound, however any audible effects were expected to be limited to audience positions nearest to concave areas of the roof, shown in Figure 2.

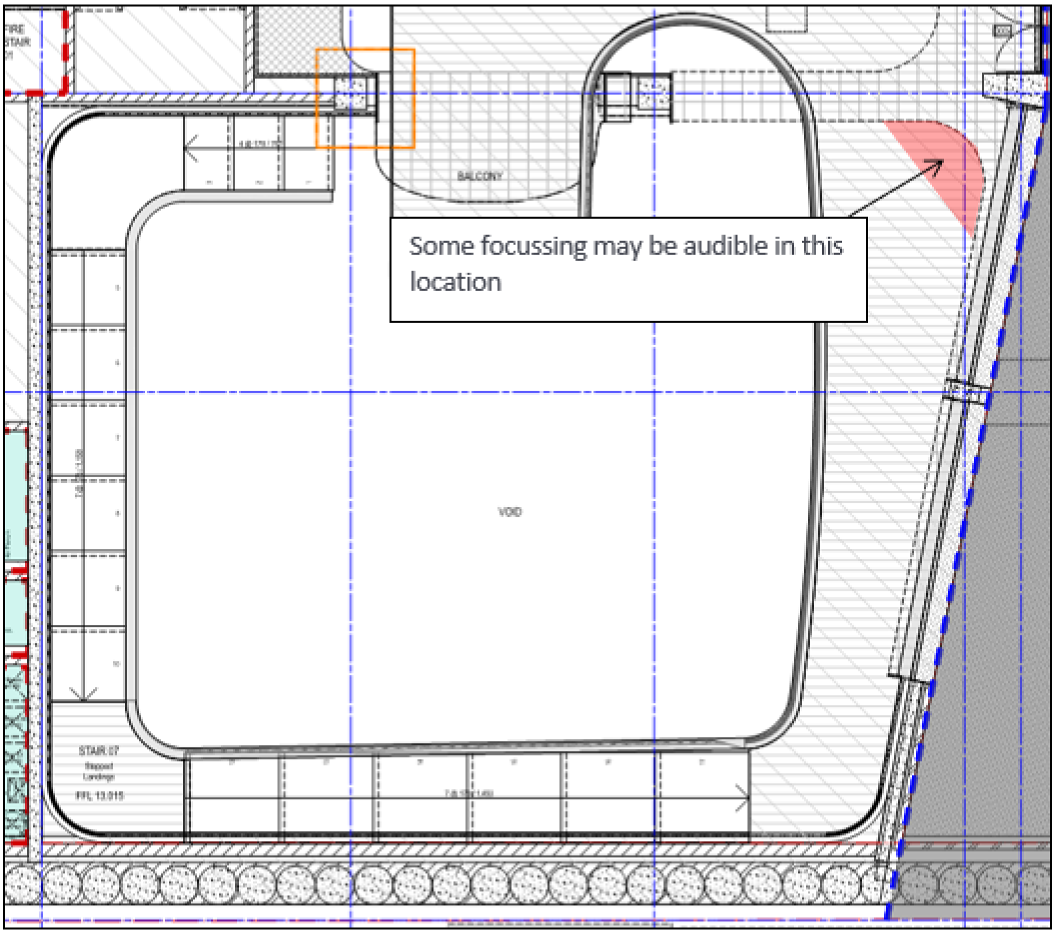

Figure 2: Identified location where focussing from concave roof elements may be audible

Reflections between the parallel surfaces of the floor and underside of the “bell” form were also identified, potentially perceptible as “flutter echo”. The provision of acoustically absorptive material on the upper bell form was considered as a potential control of this “flutter echo”.

5 GOLD LEAF DESIGN

The initial architectural design concept for the performance space was as a golden bell, with the walls and ceiling entirely gilded, comprising a gold leaf finish. Analyses had identified that a significant area of the bell would need to be acoustically absorptive. It was however established that there were no commercially available gilded acoustic panel options. Even had such panels been available, they were unlikely to match the hand guilding to be applied to the remainder of the surfaces. The following four options were considered as ways to resolve the required acoustic absorption with the gold leaf application:

1. Gold leaf gilded to non-perforated wallpaper over acoustic glasswool board
2. Gold leaf gilded to perforated wallpaper over acoustic glasswool board
3. Gold leaf gilded to acoustic glasswool board (no wallpaper)
4. Gold leaf gilded to perforated plasterboard (no wallpaper)

For the basis of the preliminary acoustic modelling, it was assumed that the thickness of the gold leaf was in the range 0.1-0.2 microns thick and applied using a thin layer of glue. It was assumed that the weight of the wallpaper was 170gsm. The thickness and weight of the gold leaf and wallpaper and the type and thickness of the glue was expected to have a major impact on the sound absorption performance achievable from any acoustic substrate.

Estimates were made of the acoustic performance of the gold leaf options above. An Odeon Auditorium (Odeon 2016) model was prepared using the various gold leaf acoustic options as well as other absorptive finishes including perforated metal to the inner face of the ramp balustrade, upholstery to the a bench seat and perforated timber to the balcony arch. The proposed extent of the gold leaf acoustic panels is shown in Figure 3.

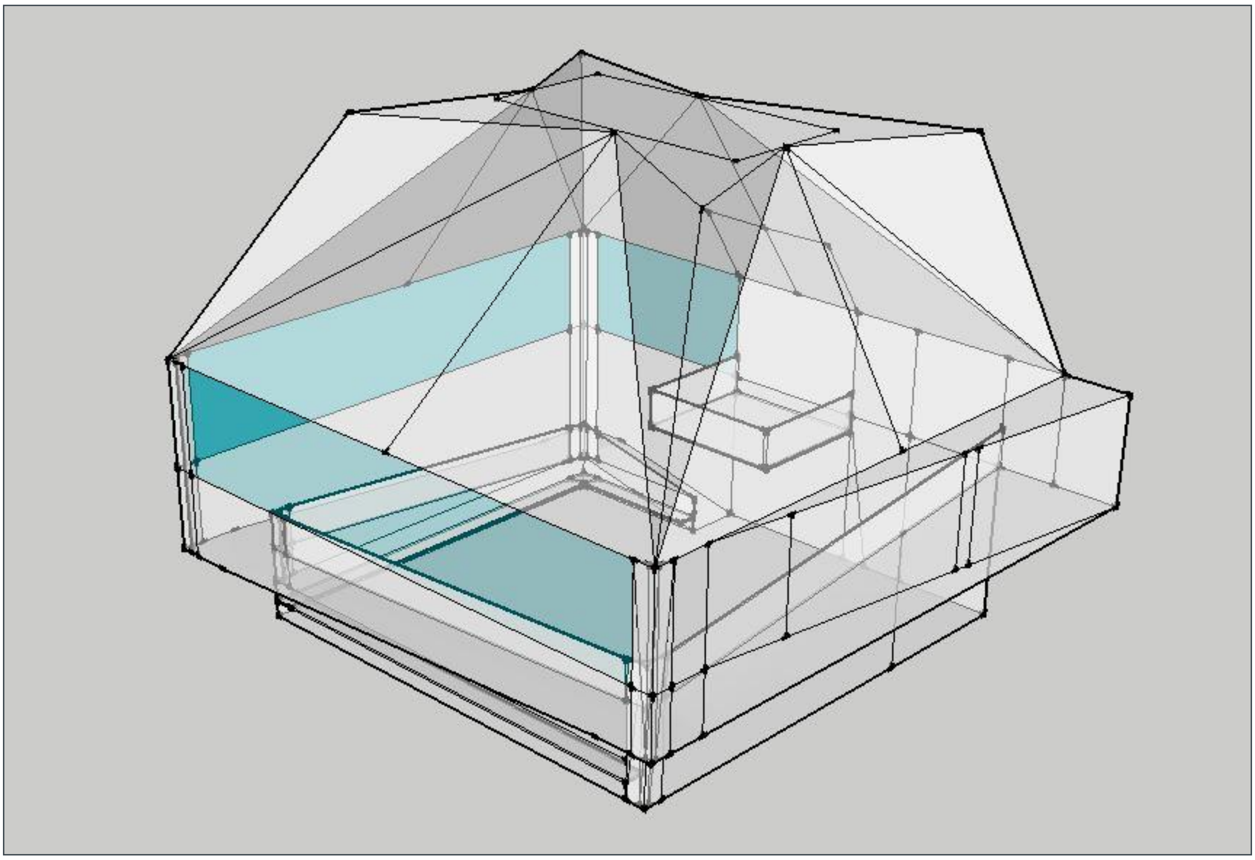

Figure 3: Location of gold leaf acoustic panels shown in blue

Eight scenarios were modelled and put to the architectural team, with predicted reverberation times ranging from 1.3 to 2.1 seconds.

The modelling identified the first option above, being gold leaf gilded directly to an acoustic glasswool, as preferred from an acoustic perspective . It was noted that this approach would limit placement of the panel to relatively flat areas of the bell and the jointing of panels would be a complex process.

Two sample gilded panels were prepared by Asona, a specialist manufacturer of acoustic ceiling and wall finishes, using Triton 50 HD96 high density 96kg/m^3 glasswool with 320 gsm glass mat composite facing (Asona, 2021) with gilding applied to the white facing of the panel. The acoustic performance of the prototype was tested in an impedence tube. The acoustic absorption performance offered by the gilded panel was lower than with the unguilded panel, particularly in the mid and high frequencies, but still offered sufficient absorption for the project. The Odeon model was updated with the tested performance and confirmed a satisfactory acoustic outcome could be achieved.

Ultimately, other factors prevailed against the proposed guilded finish and at this point the architectural concept moved away from the guilded concept to a CLT timber finish for the bell.

6 CORSS LAMINATED TIMBER DESIGN

The revised architectural concept was to use Cross Laminated Timber (CLT) layers 50mm thick, cut into curving 2D shapes offsite and stacked on top of one another on-site to form a continuous bell that would make up the performance space.

The acoustic absorption from standard CLT panel is very low, as shown below from the opinion of expected sound absorption of a solid CLT panel by the Technologisches Gewerbemuseum TGM, the German Federal Institute of Technology Acoustics and Building Physics (TGM, 2012).

Table 2: Estimated octave band Sound absorption coefficient of plain CLT panel α_s

Octave Band Centre Frequency (Hz)						
63	**125**	**250**	**500**	**1000**	**2000**	**4000**
0.02	0.03	0.04	0.04	0.05	0.05	0.05

An acoustic concept was developed to use sections of the CLT panels as slot resonator absorbers. The design involved open slots in the face of the CLT wall panels, with acoustic absorption behind. A number of design options were considered and absorption calculated, with a primary concern being around the thickness of the face panels (50mm) as well as the ratio of the thickness of the face (50mm) compared to the width of the channel opening (10mm originally considered).

A slot style configuration was developed initially, broadly as follows. The CLT panel face was to be 50mm thick. Openings would be 20mm vertically, created by deleting a section of a single lamella (the discreet strips of timber making up the layers in the CLT) and varying in length horizontally from <100mm to 1000mm (approx.). The depth behind the CLT panel would be approx. 60mm for the balustrade (inner) area and approx. 100mm for the outer wall /ceiling area below the main strong bell curve. An acoustically transparent black scrim was to be fixed to the rear of the panels to cover the slot openings. Insulation was to be installed in the cavity behind the CLT panels, being a minimum of 80mm thick to the balustrade panels and a minimum of 100mm thick to the outer wall/ceiling area. The insulation required a minimum flow resistivity of 7,500 Rayls/m.

The design ultimately evolved to a slat style absorber. To overcome potential tuning of the panels to particular frequencies the absorption spectrum was broadened by use of two different cavity depths (80mm to lower section, 100mm to upper) as well as decreasing the size of openings from 38mm at the lower extent to 1mm at the highest point.

Acoustic performance was modelled using a combination of Marshall Day Acoustic's Zorba (Zorba, 2014) software, as well tested data of a battened panel system with 50mm batten thickness. The Odeon model was updated to reflect the CLT design and confirmed the acoustic targets could be met.

The CLT acoustic panel design was relatively complex and could not be easily replicated for prototype testing. A simplified timber slat system using 60mm wide, 50mm thick battens and gaps between battens ranging from 17mm to 38mm was prepared and tested at Sydney University. The test was in general accordance with ISO 354 (ISO 354:2003), noting however that the laboratory is below the recommended room volume in ISO 354 and the test panel was also smaller than that recommended by the standard. As such the absorption, particularly at lower frequencies, was considered an estimate. The absorption coefficients of the sample shown in Table 3 were then compared to the calculated model for that configuration to confirm the model's validity.

Table 3: Sound absorption coefficient (random incidence) of prototype CLT slat panel α_s

	Octave Band Centre Frequency (Hz)					
	125	**250**	**500**	**1000**	**2000**	**4000**
Measured prototype	0.62	0.79	0.9	0.84	0.86	0.59
Calculated	0.85	0.85	0.86	0.74	0.78	0.56

Measured absorption in the 125 Hz octave band was lower than calculated, however this was skewed by a low result in the 100 Hz third octave band. Due to the reasons noted above confidence levels in the measurement at these frequencies were low. The test confirmed the acceptability of the system design and construction and installation of the CLT panels proceeded on that basis.

7 COMMISSIONING

At completion of the project, reverberation times were measured in the completed space using the IRIS 3D impulse response measurement system (IRIS, 2016). Table 4 summarised the measured reverberation time, averaged from ten measurements at two source locations and six receiver locations for each.

Table 4: Reverberation time (from T30), of completed space (s) (ISO 3382-1:2009)

Octave Band Centre Frequency (Hz)					
125	**250**	**500**	**1000**	**2000**	**4000**
1.2	1.3	1.5	1.6	1.5	1.3

The reverberation time results achieved were generally in accordance with the targets set out in Table 1. The rolloff at 4kHz was slightly less than expected. The level of rolloff at low frequencies, whilst within the target range, was greater than expected. This is likely due to low frequency absorption from the unperforated stacked CLT structure, with an airspace behind, at high levels in the room.

Other common room acoustic parameters are provided for the same measurement set in Table 5 for the readers reference. These are mid frequency (500-1000 Hz average) levels as defined by ISO 3382-1:2009, for C_{80} (musical clarity) D_{50} (speech definition), Early Decay Time (EDT) and Early Lateral Energy Fraction (J_{LF} averaged from 125-1000 Hz per ISO 3382-1).

Table 5: Mid frequency room acoustic parameters measured at commissioning

Parameter	Value
EDT (s)	1.6
C_{80} (dB)	-0.3
D_{50}	0.33
J_{LF}	0.29

The high Early Lateral Energy Fraction is worth noting, resulting from the high ratio of ceiling height to room width and depth. From an audience perspective this contributes to a very wide sound field from the musicians.
The level of diffusion in the space can be visualised by examining the 3D Sound Intensity Vectors presented in Figure 4. On the left hand side the X-Y (‘plot’ view) is shown, whilst on the right the X-Z (‘section’ view) is shown. The plots are for a source location on the ground level and a receiver on the ramp area.

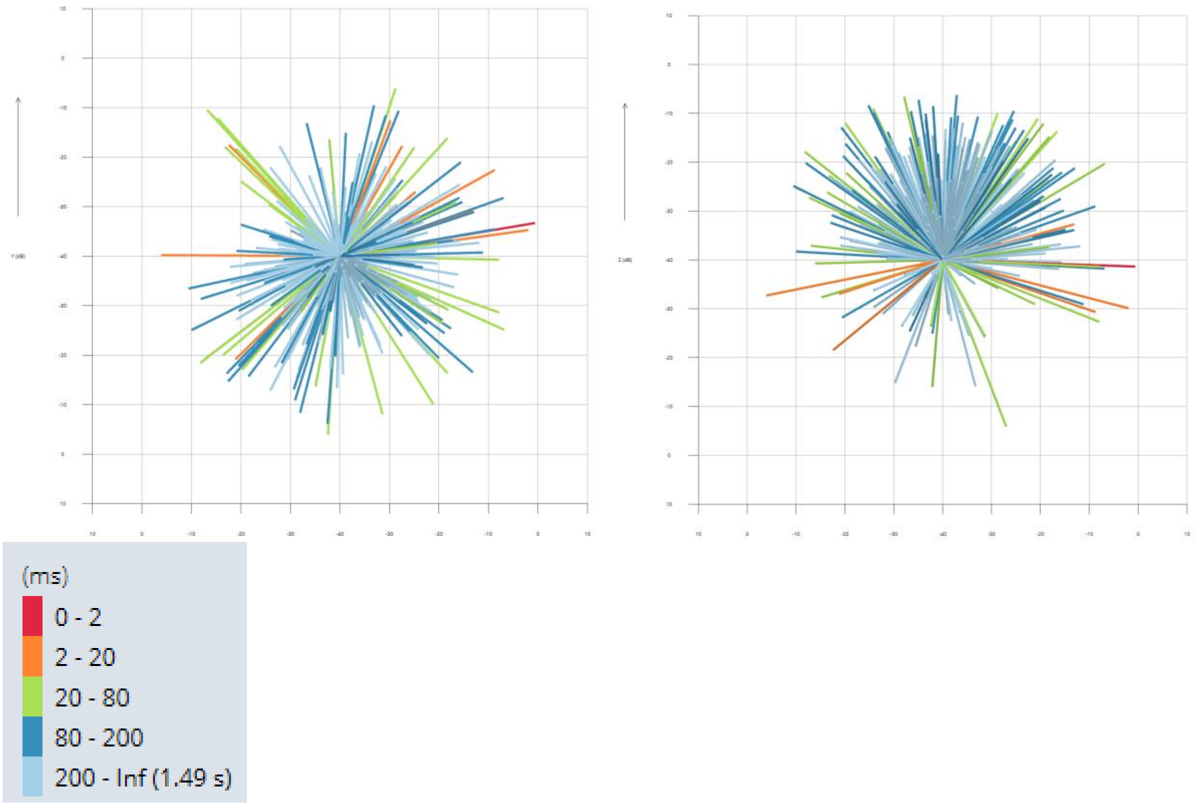

Figure 4: 3D Sound Intensity Vectors with X-Y on left and X-Z on right

The large number of early and late energy vectors confirms the diffuse reflections reaching the receiver, particularly from the sides, behind and above.

8 DISCUSSION

The Phoenix has presented a set of challenges not often encountered in the acoustic design of performance spaces; the use of the facility was never clearly defined and the architecture was intended to dictate, at least in part, the acoustic character of the space. The co-design approach to achieve the gesamtkunstwerk envisioned has resulted in a space with a unique form and acoustic character.

While the Covid-19 pandemic has limited the use of the space for performances to live audiences a series of such events have taken place in 2021. The author's subjective listening in the space with a four piece jazz band playing noted a reasonable level of clarity and clear attack but with a long room presence. The room is very diffuse with a long reverberation tail and neutral frequency balance. The room responds well to dynamics but sound engineers will need to provide amplification judiciously as too much energy in the room, or speaker placed poorly could detract from the natural acoustic. Mechanical services noise levels were very low.

The Phoenix has been well received by audiences and the architectural press. The project was awarded The Emil Sondersten Award for Interior Architecture as well as The Harry Seidler Award for Commercial Architecture at the 2020 National Architecture Awards. As the Jury citation for the Emil Sondersten Award (ArchitectureAU 2020) noted:

> *The performing and visual arts areas, located on either side of the ground floor courtyard, are fully technically equipped. However, each space's use is not defined in an orthodox way; spatial definition of function is now irrelevant. As one of a growing number of architectural collaborations being realized, Phoenix Central Park is a masterwork. In this project, the overall composition is seamlessly melded, to the point where it is difficult to decipher where one design hand ends and the other begins.*

ACKNOWLEDGEMENTS

I would like to acknowledge the client, Judith Neilson, who significantly enriched the suburb of Chippendale with this and other projects as well as the architects at both Durbach Block Jaggers and John Wardle & Associates. I thank my many Marshall Day Acoustics colleagues who worked on the project, including Gillian Lee, Alex Stoker, Simon Connolly, Hugo Caldwell and Peter Exton as well as ex-employees Michael Dowsett, Aaron James and Justin Hillis.

The Phoenix as well as Marshall Day Acoustic's offices are constructed on the lands of the Gadigal people of the Eora Nation, who are the custodians of the land on which they stand. This paper was prepared during the Covid-19 lockdowns on the lands of the Terramerragal people of the Kuringgai. I acknowledge the Gadigal and the Terramerragal and pay my respect to their Elders, both past and present. I hope we will work together to care for these lands better than they have been for the last 240 years. Always was, always will be, Aboriginal land.

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