



# Acoustic Design for Queensland Ballet's Thomas Dixon Centre Refurbishment

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**Abstract** - In a near decade long process, the state heritage listed home of the Queensland Ballet, the Thomas Dixon Centre (TDC) has been redesigned and undergone extensive refurbishment and extension works to transform into a world-class facility and new cultural hub for Brisbane. The refurbished home now accommodates new dance studios, a performance space and wellness centre, expanded wardrobe and production facilities together with function spaces and café. This paper presents acoustic design aspects of the project, the problems to be solved and solutions used to deliver a successful outcome for Queensland Ballet and the design team.

## 1 INTRODUCTION

The project is situated on Montague Road in the inner-city suburb of West End in Brisbane. The refurbishment joined a new main structure to the existing 1908 brick building so that the overall complex now houses all the features and functions desired by Queensland Ballet.

The Ground floor provides the main entry, box off/reception, lobby, promenade and cafe; private office, art finishing, workshop, wardrobe and production areas; Pilates & gym, change, dressing, fitting, wig, locker, quiet, treatment, wellness/parent and garden rooms; kitchen, laundry and loading dock; outdoor function space, dance studio 7 and the performance studio (Talbot Theatre).

The First floor provides dance studios 1-5, showers and dancer's rooms. The Second floor provides board, meeting and practice rooms, roof bar and terrace and access to the tension net for the Theatre. The Basement levels provide car and bicycle parking, storage, laundry and a bar.



Figure 1 – View of Thomas Dixon Centre Refurbishment from Montague Street.



Figure 2 – Overhead View of TDC Pre Refurbishment and Adjacent Residences



Figure 3 – First Floor Plan of TDC Refurbishment - Dancer's Rooms, Dance Studios 1-5 and Talbot Theatre



Figure 4 – View showing Closeness of Residence to Rear of Talbot Theatre of TDC Refurbishment

## 2 NOISE CONTROL

The noise control tasks for the project were to control noise between internal spaces, control the noise intrusion from external and mechanical services sources and to control noise from the facility to adjacent residential receivers, both from mechanical plant and during performance events. As can be seen in Figures 2 and 4, the residences are close to the new building and, in particular, the façade of the residence in Figure 4 is 6.5 metres from the stage rear wall of the Talbot Theatre

### 2.1 Ambient Noise

The locale is essentially a residential zone bounded by the Brisbane River on two sides with no through traffic and, consequently, vehicle movements fall off sharply after 5pm with minimal vehicle movement at night. The ambient noise levels measured were quiet in the night period and in terms of Noise Area Category, would be classified as an R2 area (low density transportation with daytime background A-weighted noise levels (LA90) in the order of 45 dBA reducing to 35 dBA in the evening and night periods). An example A-weighted one third octave band night-time ambient noise measurement is given in Appendix A.2.

### 2.2 Noise Criteria

Given that the Talbot Theatre was to be available for hire, and that this might include high volume music in the night period, the criteria for TDC sourced mechanical and event noise to residential receivers followed that for night club and music venues, octave band limits rather than a dBA limit. In addition to this, community meetings had identified that one of the nearest neighbours specifically requested a guarantee of freedom from noise disturbance for their neuro-atypical noise-sensitive child and this reinforced the choice of octave band criteria adopted, (1). Internal noise criteria were essentially that of AS2107, particularly as the WELL criteria (see Section 4) only related to office spaces.

$$Leq,oct,source \text{ at receiver (external)} < L90,oct,ambient + 5dB \quad (1)$$

### 2.3 Mechanical Services Noise

Several iterations of location and equipment types and numbers for roof top plant were involved in arriving at the final design for the externally located mechanical plant and equipment and achieving the octave band noise criteria compliance was difficult because of the closeness of residences (18 m).

The eventual solution located the plant items to take advantage of substantial barrier shielding provided by the new building form and selecting for quieter equipment.



Figure 5 – View showing the Roof Top Mechanical Plant Location

## 2.4 Talbot Theatre Noise

The Talbot Theatre/Performance Studio functions both as a space for rehearsal and the development of ballet works and as a public access venue for hire.

Given the quiet night-time ambient noise levels and the very short propagation path to the nearest residence, the strategy adopted for the control of noise from the theatre was to:

- Provide as much sound isolation as could be feasibly achieved within the constraints and
- Limit the levels within the theatre, as necessary, such that compliance with the octave band noise criteria was achieved.

That is, similar to the control of noise from night clubs and music venues, ideally with an isolation performance result that did not require performer/sound system level constraints.

The initial architectural design proposal was for a 200mm tilt up slab, however analysis of this indicated significant exceedance of the octave band criteria at low frequencies, for example by 14dB in the 63Hz octave band, assuming a representative rock band sound power level (~100dBA reverberant on theatre surfaces, see Appendix A.2). This is in part due to the coincidence dip for this thickness of concrete slab being centred around the critical low frequencies.

A double high mass masonry wall was proposed for the rear theatre wall with a large cavity (~2m) construction proposed for the roof/ceiling construction. The target sound isolation for the rear wall was 57dB in the frequency range between 50 Hertz and 315 Hertz, a tall order. It was also determined that the roof/ceiling had a leeway in transmission loss (TL) performance in the order of 10dB relative to the rear wall due to shielding and distance and a 47dB low frequency TL target was used for the roof/ceiling paths including via mechanical services/smoke exhaust.

Truncating the design iterations for brevity, the architecturally acceptable solution was to use concrete panels for the inner wall and Hebel panel for the exterior wall with an absorptively lined cavity.

Design iterations showed that the coincidence dips of both the concrete panel and the Hebel panel worked against achieving low frequency performance and, counter-intuitively, a thinner Hebel panel than the original selection resulted in improved overall performance because of the migration of the Hebel coincidence dip to higher frequency. Maximizing the structural isolation of the two masonry elements and increasing damping in the system was also incorporated into the final design. Figure 6 shows the concrete panel TL estimation (light blue curve), the Hebel panel TL (grey curve) and the system TL assuming a 230mm cavity with infill and bridging (dark blue curve). The low frequency target 57dB is indicated by the orange curve.

Having experienced the benefit of increased sound transmission loss at low frequency by smaller panel size, the effect of reduction in the concrete panel size was assessed. To do this, the panel size modification to mass law at low frequency proposed by Sewell was used (Sewell, E., 1970) and a combination was eventually found using a 0.8m by 3m concrete panel dimension that met the low frequency TL target, see Figure 7 below. Additional particulars are presented in the Appendix and given in (Vigran, T.E., 2014 and Callister J., 1999).

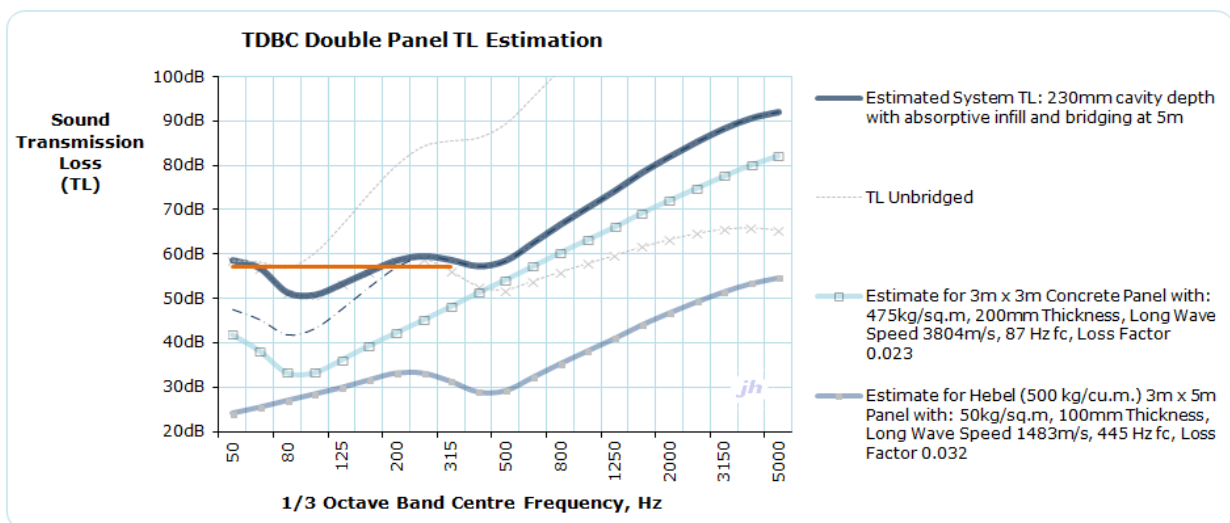


Figure 6 – Theatre Rear Wall Double Masonry Transmission Loss Estimation

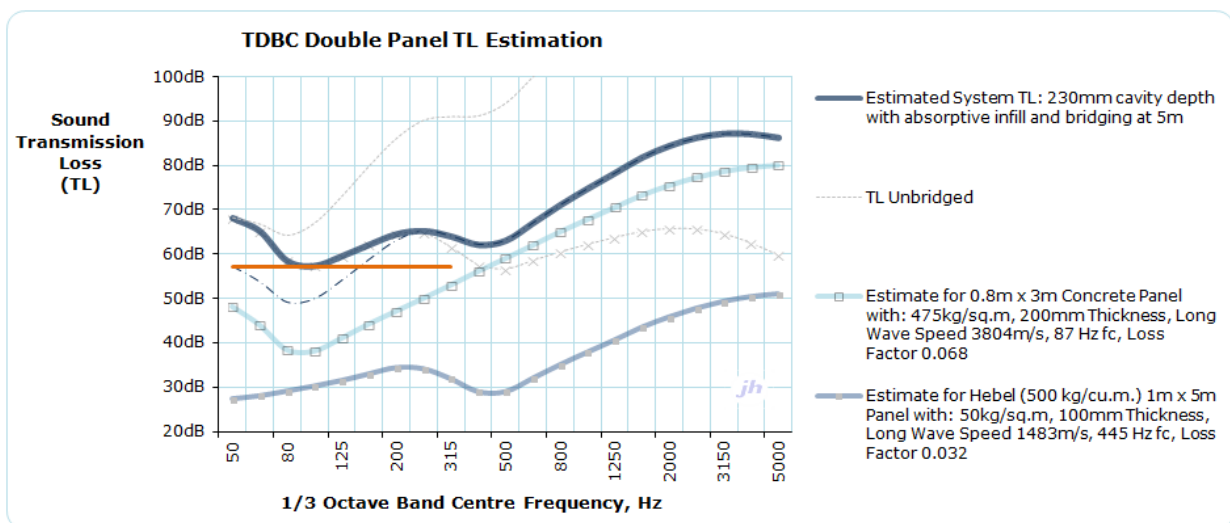


Figure 7 – Theatre Rear Wall Double Masonry Transmission Loss Estimation, Reduced Panel Size

### 3 ROOM ACOUSTICS

The majority of spaces were designed to meet the reverberation recommendations given in AS2107, generally via ceiling sound absorption treatments. In the dance studios there can be potential problems because of the desire to have expansive mirrors that are facing, on opposite walls, allowing a horizontal sound field to persist and flutter echoes to occur. This was addressed as far as could be achieved.

Significant effort went into the room acoustic design for the Talbot Theatre given that it was intended both for ballet rehearsal & production and for general performance use via hire. It is noted that the Theatre has a tensioned net (see figure 9), as used successfully in the Queensland Theatre Company Bille Brown Theatre design, that allows unhindered production staff movement and positioning of lighting to suit a given production. The approach and philosophy to the room acoustic design used is outlined in (Hedde, J., 2016). Absorption was used to control early reflections from the rear of the stage, behind the seating and from overhead, such as off the tension net perimeter zone as shown below. Sidewalls were left reflective and there was significant wrestling between the desire for unhindered horizontal lighting capability at the side walls (for ballet) and the desired early reflection detailing.

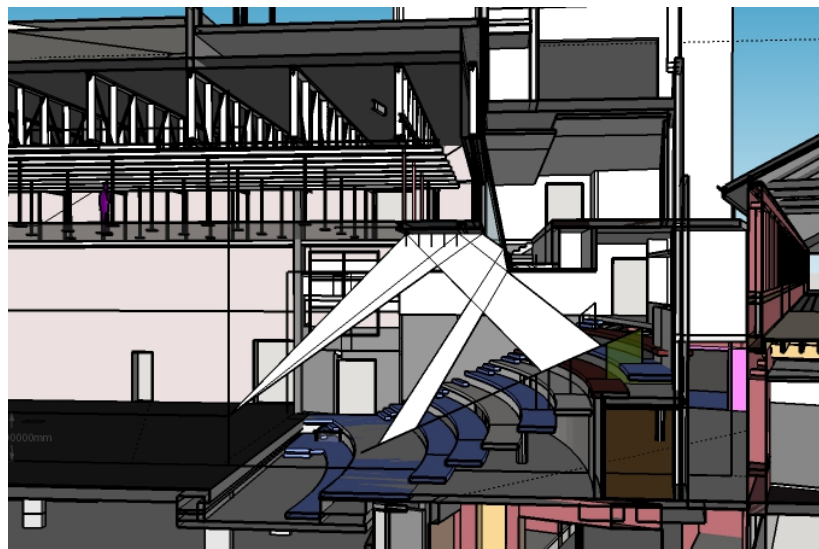


Figure 8 – Theatre Section showing an Early Reflection Analysis



Figure 9 – Talbot Theatre View of Tension Net and Towards Seating

## 4 WELLNESS

### 4.1 WELL Building Standard

Part of the intent for the building design, a client requirement, was to achieve an International WELL Building Institute Standard certification and on completion this was achieved at the Platinum level, becoming the first performing art organisation in the world to do so and not easily.

The acoustic aspects of the WELL v1.0 requirements fell under the general umbrella of prioritising 'wellbeing' for users of the building and the community with the aim of enhancing 'acoustic comfort'. A brief summary of the acoustic WELL requirements follows:

- Section 74 - External Noise intrusion to be limited to 50dBA.
- Section 75 – Internally Generated Noise to meet NC Levels (for open office spaces, enclosed offices, conference and breakout rooms and teleconferencing rooms - derived from US office space requirements) and a plan identifying "loud" and "quiet" zones of work to be provided.
- Section 78 – Reverberation Time. Conference rooms to have a maximum Rt60 of 0.6 seconds.
- Section 79 – Sound Masking. All open office areas to use sound masking systems with a maximum level of 48 dBA. For enclosed offices 42 dBA.
- Section 80 – Sound Reducing Surfaces. Ceiling with a minimum NRC of 0.9 for open office spaces and minimum NRC of 0.8 for 50% of the ceiling area for Conference and Teleconferencing rooms. Minimum NRC 0.8 for at least 25% of the area of surrounding walls for open offices, enclosed offices, conference and teleconference rooms. Cubical offices to have head height partitions with minimum NRC 0.8.
- Section 81- Sound Barriers. Enclosed offices, teleconferencing and conference rooms given Noise Insulation Class (NIC) requirements. Doors connecting to the teleconference rooms, conference rooms and private offices to have either gaskets, sweeps or be non-hollow core. Also noted, for offices, conference rooms and teleconference rooms, was proper sealing of acoustically rated partitions, staggering of gypsum board seams and packing and sealing wall penetrations.

The majority of these acoustic requirements seemed to have as their source a US Public Building Service document on achieving "acoustic comfort" in "contemporary offices" (USGSACWS PBS, 2012). However, during the project design the requirements were changed to the newer WELL v2.0 and to obtain the necessary certification points there were additional hoops to jump through, including Speech Privacy Predictor (SPP) requirements, and some unclear language. For example:

- a) An annotated document is [to be] provided that indicates the projected background noise level (dBA or NC) attributable to HVAC equipment noise, external noise intrusion or a similar source (e.g., a floor plan is color-coded to indicate dBA levels between regularly occupied spaces or across façade elements).

It was necessary to request clarification of the term "background noise", which in Australia has the general meaning of the average minimum ambient noise level (LA90) whereas it transpired that the WELL meaning was the equivalent continuous noise level in a space. Given the underdeveloped/naïve nature of the WELL acoustic requirements and their focus on office environments, an Alternate Adherence Path was sent via the WELL Consultant requesting that the requirements of AS/NZS 2107:2016 Acoustics - Recommended design sound levels and reverberation times for building interiors be adopted for the project in place of the WELL reverberation time and NC levels requirements and that Rw be used in place of NIC for assessing "Adequate Wall Construction". These requests were rejected without satisfactory explanation.

In the end, the IWBI Assessor found the acoustic design merited all the desired acoustics points.

## 5 CONCLUSION

This run-through of the acoustic design for the TDC Refurbishment has been brief and necessarily truncated, omitting a number of acoustic design elements and aspects, however, it is hoped the general design process flavour and intent has been conveyed. The finished refurbishment, delayed and affected by the Covid period, has since won multiple design awards including 2023 Australian Institute of Architects State Awards: The Harry Marks Award for Sustainable Architecture; The State Award for Heritage Architecture; The State Award for Public Architecture and The COLORBOND® Award for Steel Architecture, and the client and users are very happy with the end result.



Figure 10 – Talbot Theatre View Across Stage and Seating

## ACKNOWLEDGEMENTS

The great effort by the Project Architectural Team, Conrad Gargett, and the Structural Engineers, Bligh Tanner, to solve the construction difficulties posed by the acoustic requirements/recommendations and to monitor the build process is acknowledged.

## REFERENCES

- Callister, J., George, A. & Freeman, G., 1999. *An empirical scheme to predict the sound transmission loss of single-thickness panels*. Journal of Sound and Vibration, 222(1), pp.145–151.
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- U. S. General Services Administration Center for Workplace Strategy Public Buildings Service, 2012. *Sound Matters: How to Achieve Acoustic Comfort in the Contemporary Office*. Washington, D.C.: General Services Administration Center for Workplace Strategy Public Buildings Service.
- Vigran, T.E., 2014. *Building Acoustics*, CRC Press.

## APPENDIX

### A.1 Sewell Panel Shape Function U

Table A.2 – Panel Shape Function  $U(\Lambda)$  Values x 1000

$\Lambda = b/a, \geq 1$	$1000 * U(\Lambda)$
1.0000	0.00
1.0672	0.47
1.1422	1.95
1.2266	4.59
1.2500	5.48
1.3222	8.58
1.5000	18.03
1.5583	21.56
1.7500	34.16
1.8828	43.53
2.0000	52.29
2.2500	70.87
2.3589	79.15
2.500	89.92
2.750	108.93
3.0	127.70
4.0	198.79
5.0	262.65
6.0	319.85
7.0	371.39
8.0	418.19
9.0	461.00
10.0	500.41
15.0	660.79
20.0	781.58

Sewell's equation 52 (p 28, Sewell, E., 1970) for the panel shape function was recalculated giving the values in the table above. These were in agreement with and extended Sewell's values. A slightly more robust and compact formula than Sewell's 6<sup>th</sup> order polynomial for the shape function U is given by:

$$1000 * U(\Lambda) = \frac{2948}{e^{\left[\frac{(\Lambda-0.893)}{39.531} - 0.39\right]}} - 0.122 \quad (\text{A.1})$$

This can then be used in the expression proposed by Sewell for the radiation factor for an incident diffuse field:

$$\left[ \ln(k\sqrt{A}) + 0.16 - U(\Lambda) + \frac{1}{4\pi k^2 A} \right] \quad (\text{A.2})$$

, where  $\Lambda$  is the ratio of the panel sides (largest b to smallest, a), S is the area of the panel m<sup>2</sup>, f is frequency Hertz, c is the speed of sound in air m/s and  $k = \frac{2\pi f}{c}$ .

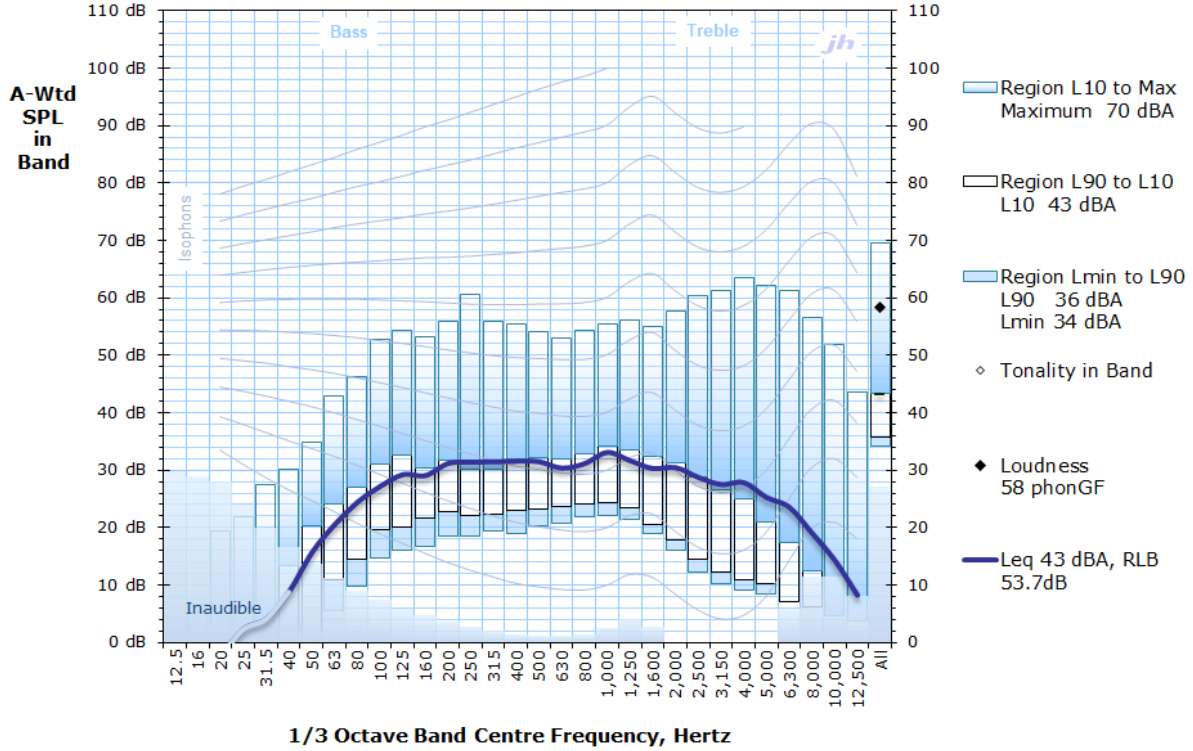
Below half the coincidence frequency of a finite panel the sound transmission loss is given by: (A.3)

$$TL(\text{dB}) = -10 \log_{10} \left\{ \frac{\ln(k\sqrt{A}) + 0.16 - U(\Lambda) + \frac{1}{4\pi A k^2}}{\left[ \left( \frac{\mu \pi f}{\rho_0 c_0} \right) \left( 1 - \frac{f^2}{f_c^2} \right) \right]^2} \right\}$$

,  $f_c$  is the panel coincidence frequency,  $\rho_0$  is air density kg/m<sup>3</sup>,  $\mu$  is the mass per unit area of the panel, kg/m<sup>2</sup>.

### A.2 Ambient Noise Measurement and Allowable Theatre Levels

**Old Ballet Rear Boundary Ambient, Combined Sampling for Design. Sources: Vehicles on Montague Road, Delivery Truck to and Mechanical Plant at the Stores. 22:43 Sun, 19 Nov 2017**



**Allowable Internal Octave Band Sound Pressure Levels. Receiver at 7m. Noise Criterion: Hall LAeq,oct < LA90,oct+5. Roof: 200mm Tilt Up Slab; Walls:200mm Tilt Up Slab**

