THE ACOUSTIC DESIGN OF 'THE TRIFFID' MUSIC VENUE, BRISBANE

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Abstract

The Triffid is a new 800 capacity live music venue in the inner Brisbane suburb of Newstead, consisting of a conversion of a WW2-era 'Nissen Hut' type warehouse and an adjacent beer garden. Acoustic challenges included sound insulation design to allow performance by bands in the live room at levels above 100 dB(C) while keeping within the structural capacity of the 70-year old building structure. The semi-cylindrical room cross-section was a particular challenge for the room acoustic design of the live room, coupled with the architectural desire to preserve the visual look of the existing room with its concave shape and exposed radial 'rib' beams. The room acoustic design for the Triffid includes an innovative two-stage design solution involving hand-perforating the existing roof structure to act as a tuned resonant sound absorber, with a new roof structure external to the building to provide the required sound insulation. Additional internal room acoustic treatments were designed using the transfer-matrix absorption prediction method and modelled using the Odeon room acoustics software package. Concurrent to the main venue design, a partial roof structure for the adjacent beer garden was designed to control environmental noise emission from patron noise from the beer garden. A lightweight polycarbonate noise barrier design was developed for use in the beer garden enclosure. Noise emission from the beer garden was compared against published papers for the prediction of noise from small/medium crowds. The results of measurements taken in the completed beer garden compare closely to the predicted noise emission from comparable-sized groups of patrons.

1. Introduction

The Triffid venue is located on Stratton Street in the inner-Brisbane suburb of Newstead, in a historically-industrial area being progressively developed into a residential area. The site was originally a WW2-era 'Nissen hut' type warehouse, which was used as a storage site by Hutchinson Builders, who are acted as co-developer of the venue. The warehouse had an existing metal deck roofing system with areas of ventilation openings and no internal linings, as shown in Figure 1.

Arup was originally engaged to prepare an acoustic report for the development application to Brisbane City Council (BCC), with the engagement being extended to include the detailed design of the venue, commissioning and supporting the application for a liquor licence from the QLD Office of Liquor and Gaming Regulation (OLGR).

BCC has declared Australia's first Special Entertainment Precinct (SEP) in the inner suburb of Fortitude Valley. Within the SEP, additional planning controls apply to provide a balance between music venues and new residential development, and the normal noise criteria for licensed premises contained in the Liquor Act 1992 and Liquor Regulations 2004 do not apply. These controls require a minimum façade performance for new residential development, balanced with noise limits for music venues that apply at 1 m from the venue.

However, the SEP has not been extended to cover the recent development of several licensed premises in the adjacent suburb of Newstead, with the boundary of the SEP running along the centreline of Stratton Street itself – resulting in the Triffid being just outside the precinct.

This results in a complicated compliance regime where the Triffid itself is located outside the precinct and is subject to the full assessment requirements of the Liquor Regulations, in addition to BCC's own development approval conditions, but where some of the nearest noise-sensitive receivers are located within the SEP.

Figure 1. Original condition of the venue prior to redevelopment

2. Noise Sensitive Receivers

The surrounding area is currently predominantly industrial/commercial, with the nearest existing noise-sensitive receiver being the Emporium mixed-use development (approximately 200 m from the Triffid), which includes a hotel and residential apartments. However, the Emporium is located between Wickham Street and Ann Street, which are busy arterial roads forming the main eastern access route to the Brisbane CBD, and therefore the Emporium site has significant traffic noise exposure.

Further, the most-exposed façade of Emporium is the hotel, which has a sealed façade with secondary glazing on large airgap and an apparent façade performance of approximately R'_w 45 dB (as determined from site surveys).

Site surveys indicated that the most-sensitive existing receivers would be the low-rise residential receivers located in the vicinity of Light Street, Fortitude Valley, on a small hill approximately 300 m to the north-west of the venue. Despite the greater distance, the ambient noise levels at the Light Street receivers were significantly lower than at the Emporium.

During the design process for the Triffid, construction commenced on several new residential buildings within 100 m of the venue. The most-exposed of these new buildings are the Metro Waterloo development (located across Stratton Street to the north of the venue) and the apartments at 6 Kyabra Street, which are located ~15 m immediately to the south of the venue.

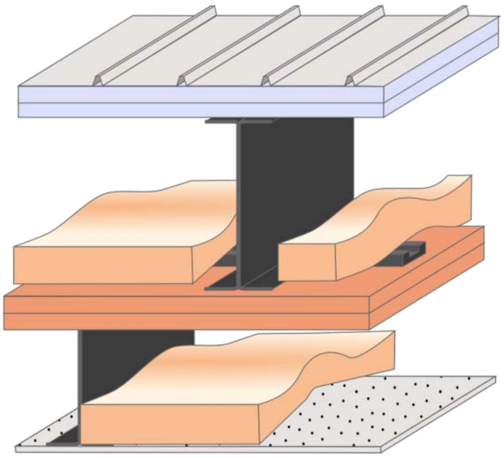
3. Façade Design

The existing façade of the venue had a single skin metal roof, with an approximate acoustic performance of R'_w 15. This was not sufficient on acoustic or fire grounds, and required upgrading including additional mass layers for fire protection and increased sound insulation. Given the age of the building, the amount of additional mass that could be added was limited by the capacity of the existing building structure.

The desired operational noise level within the venue is L_{eq} 110 dB(C) at the front of the mezzanine, which poses a significant challenge to provide sufficient sound insulation to comply with the OLGR and BCC noise requirements with the nearest receiver (6 Kyabra Street) approximately 15 m from the venue.

A complicating factor was the desire by the architect to keep the visual look of the venue largely unchanged inside – in particular retaining the expressed radial steel ‘ribs’ running along the venue. This precluded adding additional mass layers within the existing roof structure and also had implications for the room acoustic design as discussed further in Section 6.

The adopted design solution was to build a new roof system outside of the existing roof, adding multiple mass layers with intervening cavities to maximise the low-frequency sound insulation for a given overall roof mass. Additional mass layers were added as the design was developed to address noise impacts to the new apartment developments being constructed in the vicinity. The final designed roof system (with overall mass 37.5 kg/m^2 and a calculated acoustic performance of R_w+C_{tr} 45) is shown in Figure 2.



- New 0.8mm BMT zinc sheeting [5.7 kg/m^2]
- Waterproofing membranes
- 2 x 13 mm plasterboard [17.4 kg/m^2]
- 125 mm cavity on Z-girts
  with 50 mm 32 kg/m^3 insulation in cavity
- **2 x 12 mm plywood [14.4 kg/m^2]**
- *150 mm cavity with 75 mm 24 kg/m^3 acoustic absorption*
- *Perforated existing metal roof sheeting*

Figure 2. Designed roof build-up, The Triffid Music Venue

The roof design includes hinged covering hatches (2 x 6 mm fibre cement), designed to block off the smoke exhaust openings in the roof to reduce noise breakout when the venue is operating normally. In emergency conditions these hatches are designed to drop open to allow the smoke exhaust fans to operate. The rear wall of the venue (behind the stage) is 110 mm brick with a cavity between the brick and the outer façade to improve the low-frequency sound insulation of this façade, which faces towards 6 Kyabra Street.

The venue also includes several access doors to the beer garden, and a two-way bar (a converted shipping container) which connects the venue to the adjacent beer garden. All doors and hatches are fitted with acoustic seals. When the venue is operational all doors to the beer garden are closed (with access via a sound lock into the venue foyer), and the two-way bar serves the venue only.

4. Room Acoustic Design

The base room shape of the venue is extremely challenging acoustically – essentially a half-cylinder, which would normally result in strong focussing of sound onto the audience plane and poor sound quality. The surface finish of the existing metal roof is corrugated, which will also result in frequency-selective reflection characteristics at high frequencies.

Although the end client (John Collins, formerly of *Powderfinger*) has a musical background, the rest of the design team did not have much experience in the design of music venues, and the use of visual design tools such as ray tracing and sketches was an important part in conveying the importance of avoiding acoustic defects, e.g. a hand ray-traced sketch illustrating the concept of focussing in Figure 3.

As mentioned previously, the architectural desire was to have the visual look of the venue (particularly the exposed ceiling ribs) be largely unchanged, which limited the scope for acoustic intervention. In particular, it was not possible to eliminate the focussing from the concave overall room cross-section via geometry by adding any internal shaping elements or by using a suspended ceiling, which would have been preferable.

This meant that changing the surface finish of the ceiling was the only practical option, but again the opportunities to add effective sound scattering or absorptive elements were limited by the requirement not to change the look of the venue.

The solution was to take advantage of the large (minimum 175 mm) cavity between the existing roof and the new roof, add a 24 kg/m³ polyester insulation blanket in the cavity and to perforate the existing roof to turn the roof + cavity into a tuned sound absorber (with as wide a bandwidth as practicable) in order to attenuate the ceiling reflection and reduce the strength of focussing.

The existing roof was perforated on site by the contractor using the end of a crowbar to punch each hole through the roof, with an estimated >20,000 holes being hand-perforated across the venue as shown in Figure 4.

Arup provided guideline values for the hole spacing and dimensions, however the natural variation in the hand-perforation process means that the roof will inherently have a wider bandwidth (at the expense of the peak absorption coefficient) because of this variation. The roughness associated with the protruding edges of the perforation will also add some minor (if unquantifiable) sound scattering benefit.

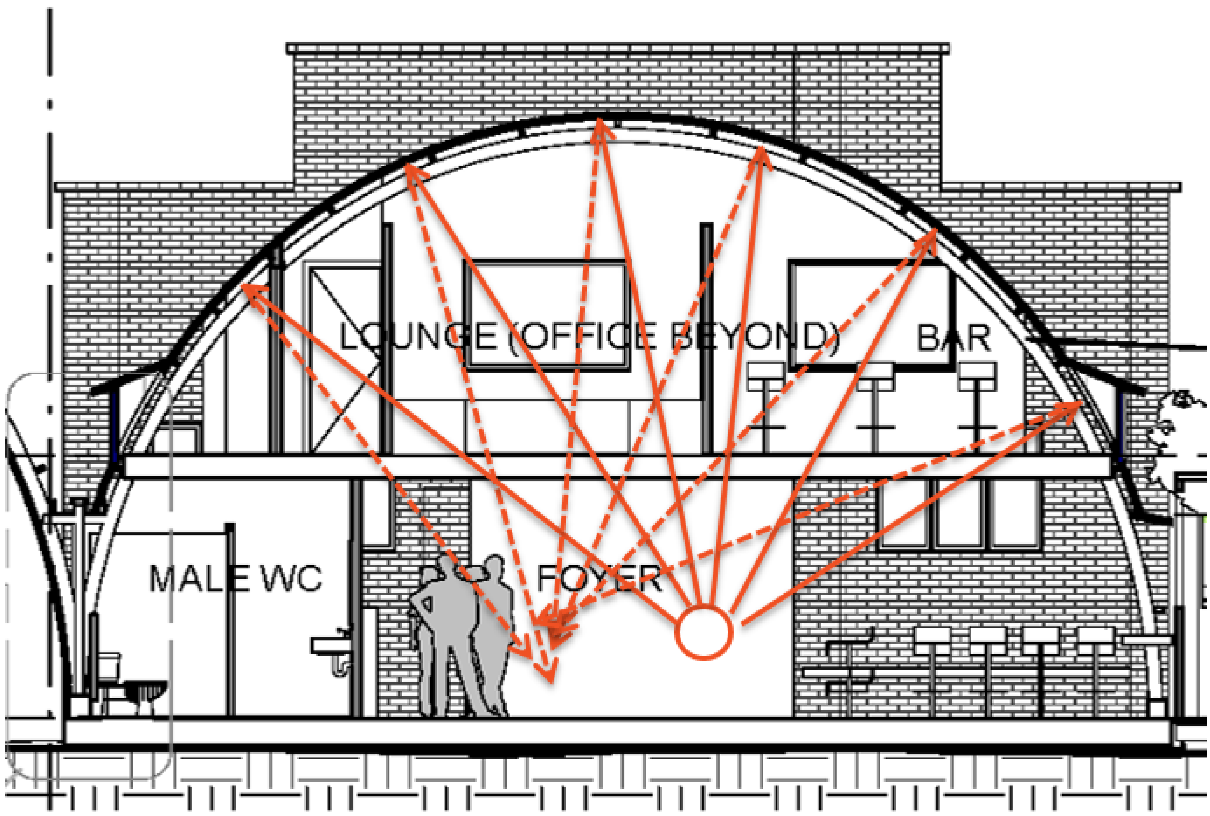


Figure 3. Cross-section sketch of The Triffid showing potential acoustic defect from focussing

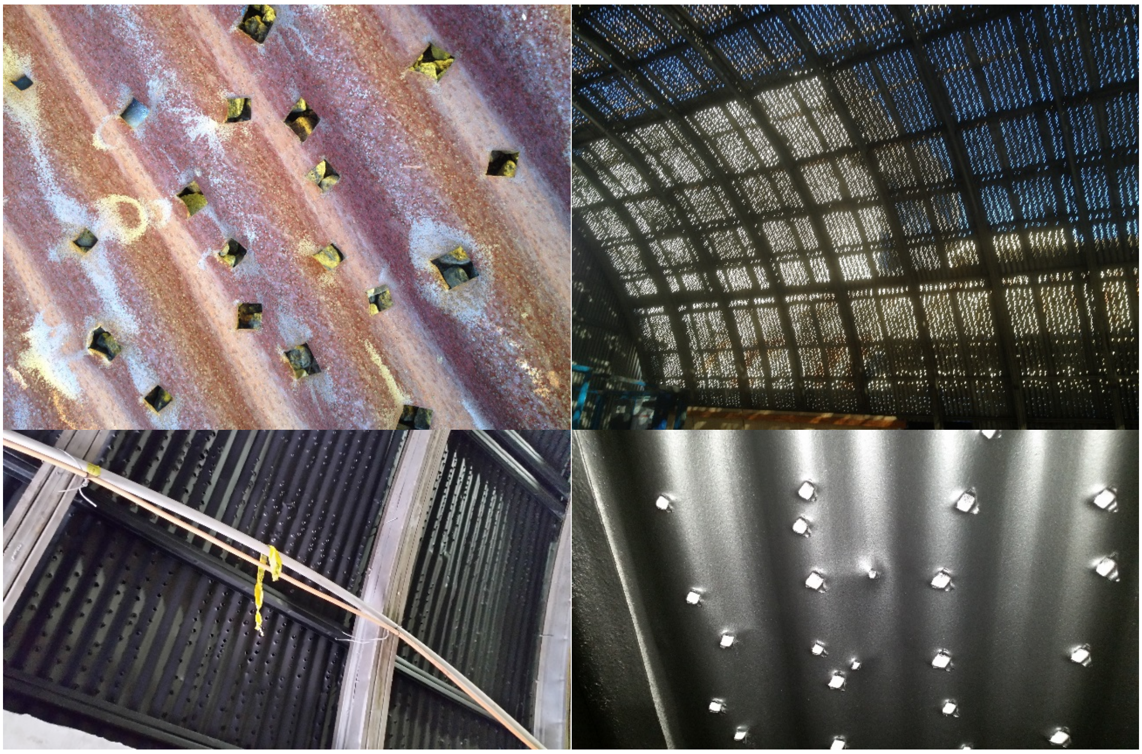


Figure 4. Perforated roof system of The Triffid. Upper row is before installation of the outer (new) roof system. Lower row is after installation of cavity insulation and painting of the roof.

Where acceptable architecturally, the absorptive roof was supplemented by 32 kg/m³ polyester acoustic panels within the room itself. The locations of these panels were designed using an Odeon room acoustic model of the venue. The additional panels are generally 100 mm thickness and are located above the stage zone (in order to provide a controlled environment on stage) and at the rear at the venue above the mezzanine (to address potential 2nd-order echoes back to stage), with some ‘bands’ of broadband absorption running transversely along the entire venue to interrupt focussing. 100 mm wall acoustic panelling on the wall behind the stage and 50 mm panels on the rear wall of the venue was also installed to improve stage conditions and to treat a potential echo from the flat rear wall of the main audience area, which is at the same height as the stage and loudspeaker stacks.

Unlike a traditional installation where acoustic panelling is generally mounted with a rigid backing, the ceiling panels were deliberately mounted with an airspace behind, effectively turning these sections into a “two-stage” sound absorber where the in-room panel and the perforated roof system act in tandem to increase the overall sound absorption. Both low-frequency and broadband absorption panels were designed, although only the broadband panels were actually installed in the finished venue. The low-frequency performance of the finished venue is sufficiently controlled that no additional bass absorption was considered necessary when commissioning the venue.

The absorption coefficients of the perforated roof and the in-room panels were predicted using the transfer-matrix approach discussed in Cox and D’Antonio [1], which allows normal-incidence absorption coefficients to be predicted based on the flow resistivity of the cavity infill and the perforation geometry. Because of the cylindrical cross-section of the venue, incident sound on the ceiling will be very close to normal-incidence and hence this approach allows the sound absorption properties of the ceiling to be estimated with some confidence without requiring laboratory testing (which would be impractical as it would require a section of the roof to be sent to a test laboratory).

The predicted absorption coefficients of the perforated roof and the roof + broadband absorber and roof + bass absorber panel systems are shown in Figure 5. In octave-bands, the perforated roof itself provides effective (>0.5) absorption from 250 Hz to 4 kHz, while the broadband absorption provides effective absorption from 125 Hz to 8 kHz and the bass absorber provides effective absorption at 63 Hz. Images of the finished venue are shown in Figure 6.

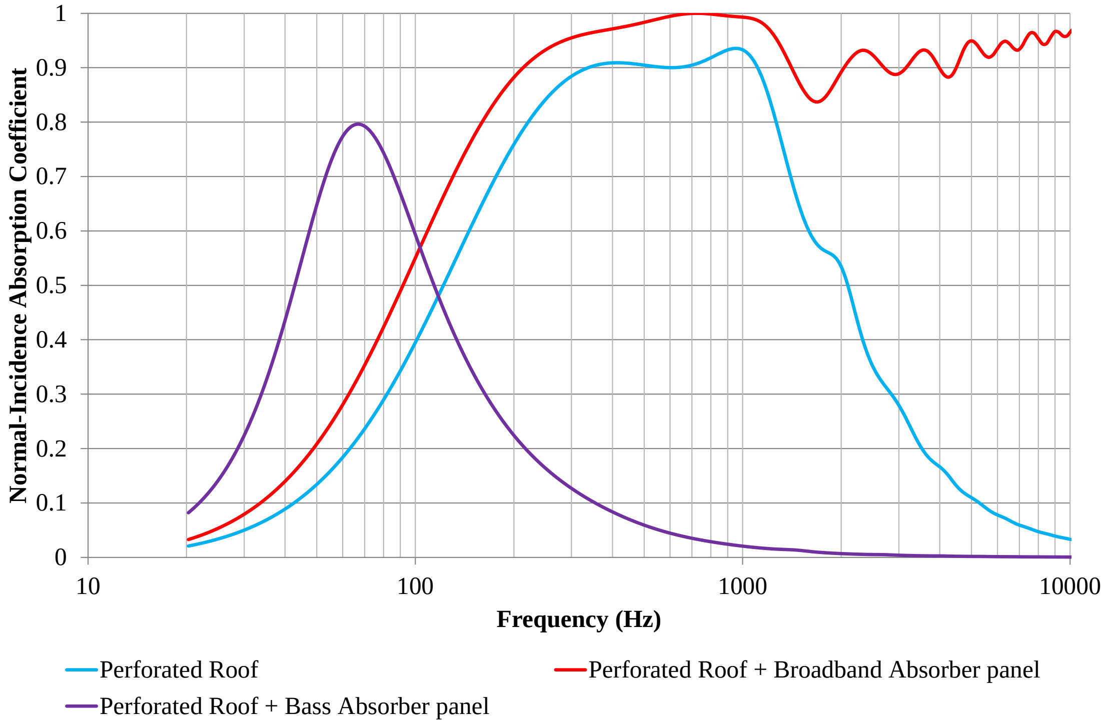


Figure 5. Perforated roof system of The Triffid. Upper row is before installation of the outer (new) roof system. Lower row is after installation of cavity insulation and painting of the roof.

Figure 6. Finished venue images, The Triffid.

The measured unoccupied reverberation time (T_{30}) in the Triffid is shown in Figure 7. Reverberation time was measured using the house sound system as the sound source using a swept-sine signal measured using a DPA 4006 omnidirectional microphone via WinMLS software. The presented values are the arithmetic average of measurements at nine receiver points: seven across the main floor of the venue (including the sound desk location) and two in the mezzanine. The measurements show a consistently flat spectrum from 125 Hz to 2 kHz with a modest bass rise of 15%

at 63 Hz. The spatially-averaged mid-frequency musical clarity (C_{80}) across the main floor is 7.0 dB (125 Hz – 4 kHz, unoccupied).

The subjective listening experience in the venue is a very clear and balanced sound, with well-controlled bass that sounds "powerful" without becoming "boomy". During one concert with an amplified string ensemble on stage, there was some high-frequency harshness audible from the corrugated surface finish of the venue roof; however when used more-typically for a band this is not as evident due to the reduced frequency content at very high frequencies. The room acoustic treatment has successfully reduced the strength of the focussing such that it does not significantly affect the venue sound (although it is just perceptible to a trained ear when standing on the centreline of the venue). The feedback from bands and visiting sound engineers regarding the venue sound (particularly the sound on stage) has been very positive. An example energy-time curve measured mid-floor in the centre of the venue) is shown in Figure 8.

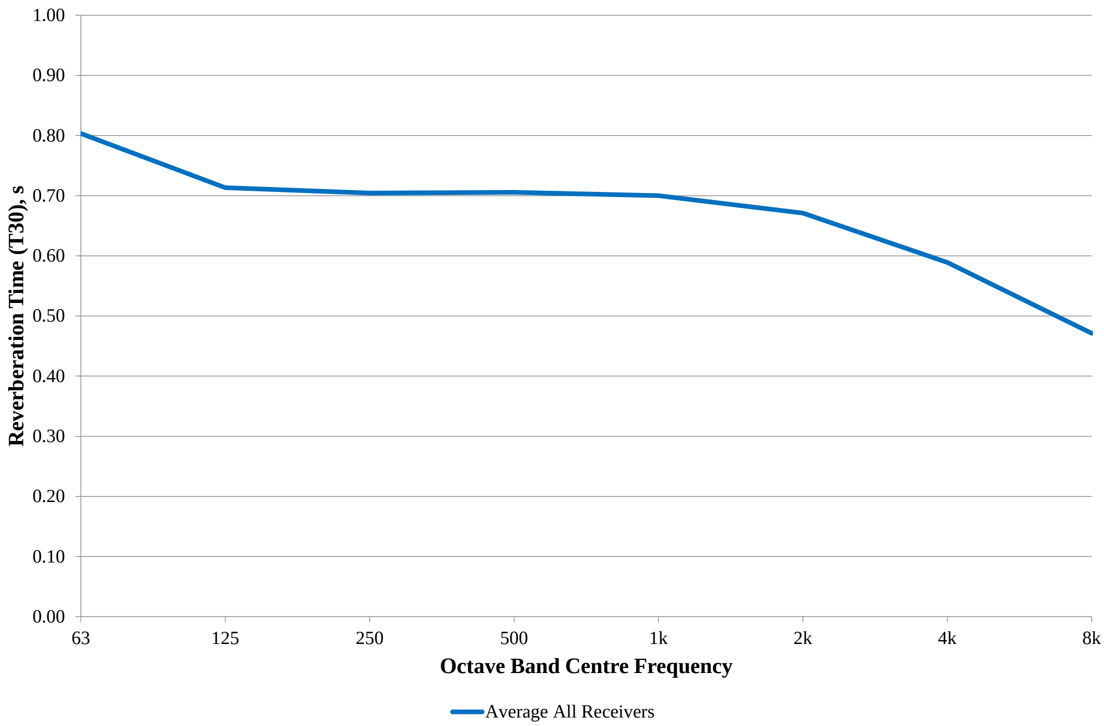


Figure 7. Average unoccupied reverberation times, The Triffid venue

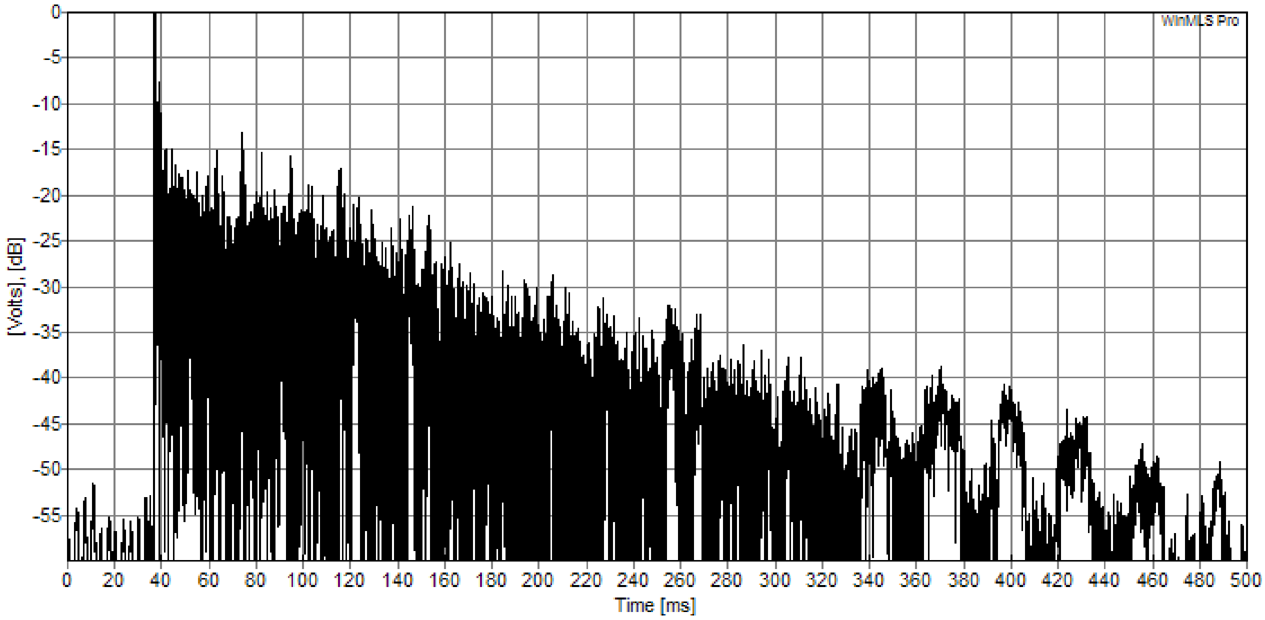


Figure 8. Energy-time curve measured on centre of main floor of Triffid

5. Beer Garden Noise Control

The final major component of the design of the Triffid venue was providing noise attenuation to control noise break-out from the adjacent beer garden. Initial environmental noise modelling indicated that the A-weighted noise breakout from the venue would be dominated by beer garden noise, and that acoustic screening of the beer garden was necessary to control noise break-out to existing residential receivers located to the north and west of the venue (e.g. Emporium and Light Street).

During ongoing design, the development of the adjacent 6 Kyabra Street site into residential apartments also necessitated the design of noise mitigation measures to control noise breakout from the beer garden to the 6 Kyabra Street apartments, located at the southern end of the beer garden.

The noise mitigation design evolved from providing a noise barrier across the Stratton Street frontage of the beer garden into designing a partial roof structure (with a gap in the centre) to shield adjacent receivers from beer garden noise while still keeping the open character of the beer garden. This roof has been designed in two stages: the first stage (already constructed) at the northern end of the beer garden provides mitigation to existing receivers to the north, while a second stage (to be constructed prior to the completion of the 6 Kyabra Street apartments) provides mitigation to future receivers to the south.

For fire safety reasons, a 3 m clearance had to be maintained between the roof structure and the neighbouring building. This gap results in a complicated semi-reverberant noise propagation environment for noise breakout from the beer garden where reflected as well as diffracted sound will be a significant contributor to the received noise level at adjacent residential premises.

Figure 9 shows a render in the 3D model of the beer garden looking towards the 6 Kyabra Street apartments showing the shielding benefit provided by the designed Stage 2 roof structure and the fire clearance gap to the adjacent wall.

The acoustic performance of the beer garden partial roof was modelled using Odeon software, enclosing the venue (and surrounding apartments) in a large 100% absorptive ‘bounding box’ in order to create a ‘room’ for the Odeon simulation. The number of rays was increased over a traditional room model to provide sufficient ray density to obtain reliable predictions at the receiver, as determined by a sensitivity study.

Odeon was used in preference to traditional environmental noise modelling programs (e.g. SoundPLAN) because the semi-reverberant conditions with significant reflection paths present in the propagation scenario are beyond the capability of current environmental noise software. Over the short (<100m) propagation distances involved to the nearest receivers, Odeon’s inability to model meteorological effects is not significant.

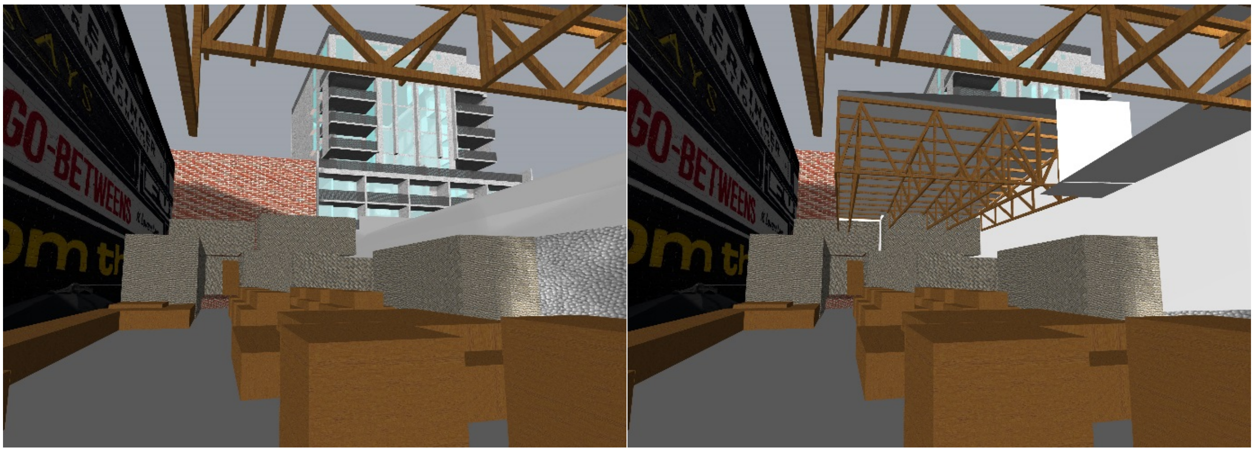


Figure 9. 3D model looking towards 6 Kyabra Street apartments showing designed Stage 1 (left) and Stage 2 (right) roof of beer garden and fire safety gap between roof and adjacent wall

Source levels in the beer garden were modelled using the Hayne et al [2] methodology, which provides a relationship between the sound power level from a group of patrons and the group size N as follows:

$$L_w\ (L_{A10}) = 15 \log N + 67 \tag{1}$$

Assuming a nominal occupancy of 250 patrons, this results in a source sound power level of 103 dB(A) within the beer garden. This sound power was divided between 10 individual point sources, representing groups of patrons, in order to predict a semi-reverberant level within the beer garden of 83 dB(A). Background music noise levels in the beer garden were modelled using the loudspeaker layouts and loudspeaker directivity data provided by the project AV consultant.

Measured sound levels in the Triffid beer garden during commissioning testing in January 2015 (~50 patrons in beer garden) and March 2015 (~100 patrons) were compared against the predicted Hayne et al sound levels for the same nominal occupancies, with the predicted A-weighted levels corrected using an assumed spectrum shape based on published speech spectra [3]. Figure 10 summarises the measured vs predicted noise levels, which show very close agreement both in A-weighted values and in the frequency spectra. Note that the measured noise levels at low-frequency are affected by background music noise in the beer garden.

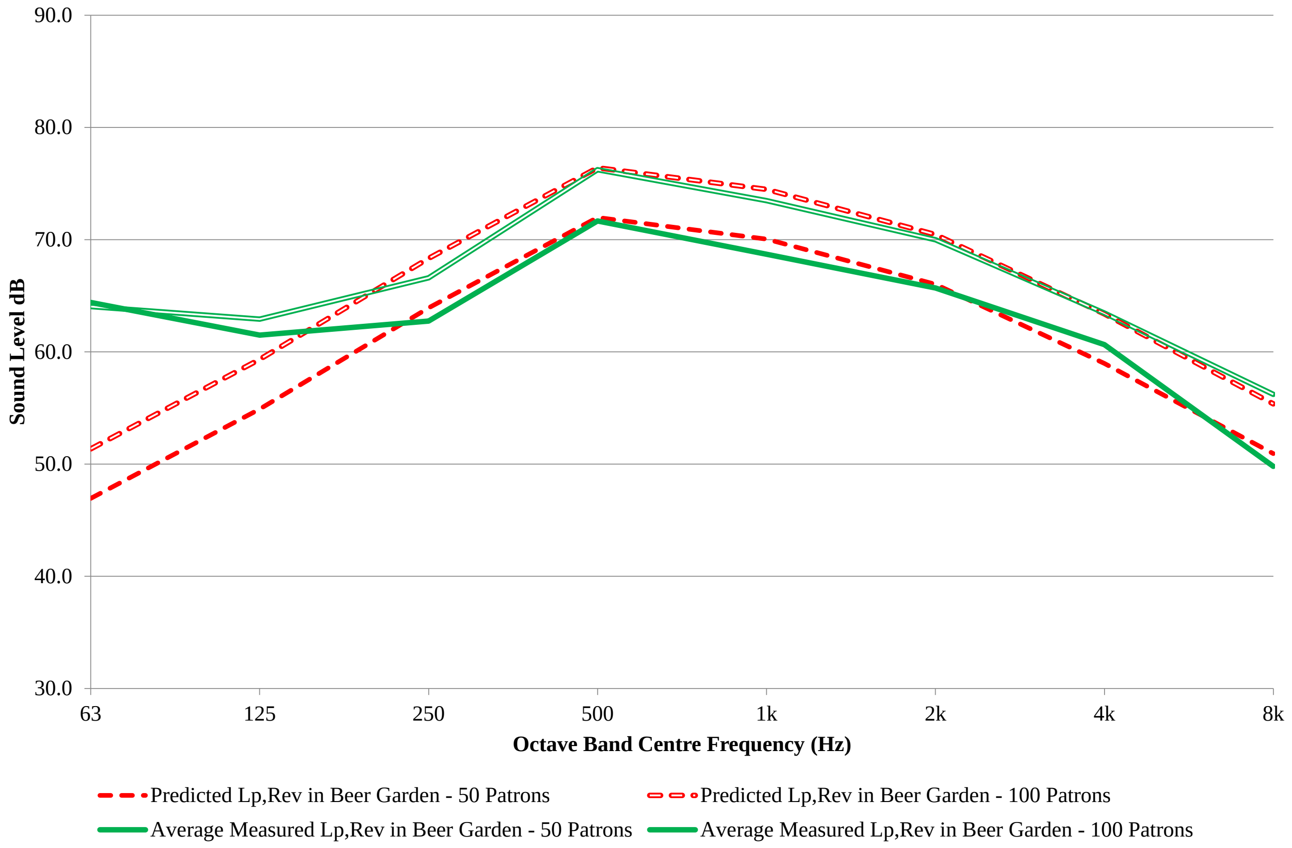


Figure 10. Comparison of measured and predicted patron noise levels in the beer garden

The roof (and noise barrier at the Stratton Street entrance of the beer garden) were implemented using a lightweight polycarbonate structure with overall mass ~6 kg/m². Equivalent performance to a traditional noise barrier (with mass >10 kg/m²) was obtained by incorporating a cavity with timber studs between a layer of expanded polycarbonate roof sheeting and a layer of 4.5 mm solid polycarbonate, as shown in Figure 11. Doors and windows in the noise barrier are kept closed after 10:00pm.

Figure 11. Lightweight polycarbonate noise barrier and roof system, beer garden

To supplement the acoustic performance of the partial beer garden roof, the worst-affected apartments at 6 Kyabra Street will be fitted with balcony soffit-mounted acoustic absorption (using a suitable outdoor product such as *Reapor* or *Coustone*) in order to reduce the noise levels on balconies and (in turn) the noise break-in to bedrooms. Soffit absorption at 6 Kyabra Street is predicted to provide a noise reduction of between 2-7 dB(A), with greater attenuation predicted for higher floors where the angle of incidence results in most sound energy reflecting off the soffit.

Balcony noise levels at 6 Kyabra Street are predicted to comply with the BCC and OLGR noise requirements via the combination of the partial roof over the beer garden and soffit treatment at the apartments, despite the short distance (~15 m) of the venue from the apartments.

6. Summary

The Triffid music venue involved several acoustic challenges in its design. The fundamental venue shape was unfavourable, particularly for heavily-amplified music, while the location of the venue in close proximity to future apartment developments and the lightweight nature of the existing building structure posed significant challenges in providing sufficient sound insulation for the venue. The aesthetic and functional constraints on the venue design required an innovative approach to provide the required sound insulation and room acoustic treatments as part of a single building element, which in turn allowed the acoustic treatment to be effectively concealed to have minimal impacts on the architectural character of the venue. The challenge of achieving sufficient noise control to operate a beer garden of up to 250 patrons approximately 15 m from the nearest residential receiver required careful acoustic design and advanced modelling in order to design a noise mitigation package via a combination of source and receiver treatments. The finished venue is approaching the end of its first year of successful operation and has been warmly received by the Brisbane live music scene and visiting bands alike, both for the quality of its acoustics as well as the unique character and ambiance of the venue.

Acknowledgements

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