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ACOUSTIC DESIGN OF TWO FILM SOUND STAGES NEAR A TRAIN LINE

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ABSTRACT

The Auckland Film Studios (New Zealand) site has recently expanded its facilities with the construction of the Te Pūtahi building. This includes two large sound stages (2,000m^2 each) which provide a word class facility for film production. The project location, situated in an industrial area and near a train line, required careful acoustic consideration of the constructions to ensure a low background noise. While precast concrete walls typically used in soundstages would provide the required sound insulation performance to control airborne noise ingress, reradiated noise from the vibration generated by train pass bys was identified to exceed the design specification with this construction. A simple and robust alternative design, with a double layer construction, was developed to reduce reradiated noise, but still provide adequate airborne sound insulation and reduce the risk of construction errors. Furthermore, an auralisation demonstration of train pass bys was also prepared during the design process to assist the design team and client to understand the effects of building materials in the audibility of trains in the studios. This paper outlines the design process and technical solutions developed to achieve the required design specification.

Keywords: *sound stages, train, reradiated noise, auralisation.*

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1. INTRODUCTION

Sound stages are an essential part of the filming production process. These provide a controlled and versatile environment for filmmakers to explore and make their ideas reality. Sound stages are typically large empty rooms with high ceilings, structural grids to support lighting, curtains and other equipment or props used during filming and building sets.

A low background sound and a controlled internal environment are essential in a soundstage. With sound stages often located in industrial areas or main transport areas, the acoustic design is a key element of the success of the sound stages.

Auckland Film Studios in New Zealand, has recently expanded their facilities with the Te Pūtahi sound stages. The Te Pūtahi building, which includes two sound stages (2,000 m^2 each) in one building, is located in a moderately high noise environment, within an industrially zoned area and approximately 25m from a train line. The project was developed by Tātaki Auckland Unlimited and was co-funded by Government and Auckland Council.

Thanks to active client engagement and a detailed and well-coordinated design, an excellent outcome was achieved - a high-performance facility was delivered which readily met the client's expectations.

In this paper the authors describe the design challenges and decisions undertaken during the design of Te Pūtahi sound stages.

2. SITE LOCATION AND EXISTING NOISE ENVIRONMENT

2.1 Site location

The Auckland Film Studios site is located in an industrial zone with the rail corridor approximately 25m from one of the Te Pūtahi sound stages (see Figure 1 and Figure 2).

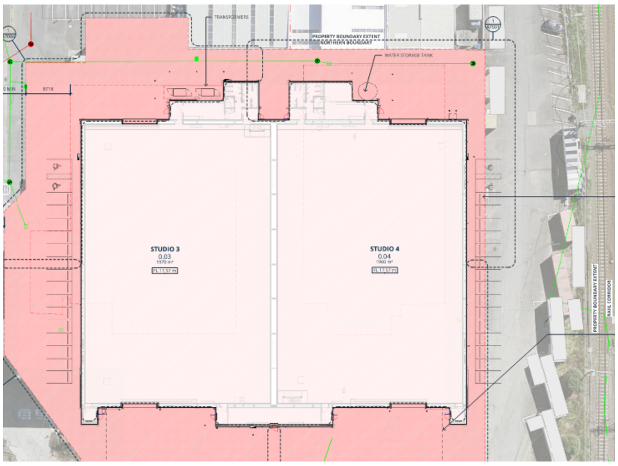

Figure 1. Location of Te Pūtahi sound stages[1]

Figure 2. Te Pūtahi building during construction[2]

2.2 Existing noise and vibration environment

2.2.1 Noise environment

According to the noise regulations, adjacent sites can generate noise levels of up to 65 dB L_{Aeq} at the site boundary of Auckland Film Studios.
The sound stages are exposed to noise from other sites, but also noise from adjacent roads and train pass bys.
A noise logger was installed at the proposed location of the building for one week. A detailed analysis of a representative day was undertaken and the noise sources and design level discussed with the client. An incident level of 72 dBA was decided as the design level - this would cover the noise from passenger trains as well as other ambient sources. The design level is shown in Figure 3 with a horizontal red dashed line. Noise from some film related activities within the site exceeded this level for short durations of time, but we were informed these could be managed and should not be considered. Nevertheless, based on the noise data measured, the ambient noise levels would only exceed 72 dBA approximately 2 minutes per day.

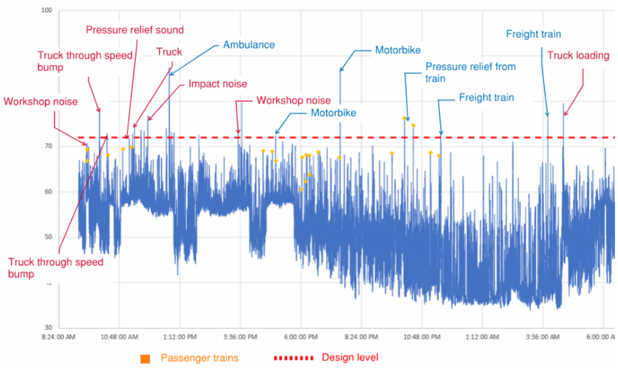

Figure 3. Analysis of noise levels measured

2.2.2 Vibration from trains

There was an existing building in the same location as the proposed soundstages. Vibration levels were measured during one week at this location. Trains pass bys were the main vibration source, and while the vibration was moderately low and subjectively barely perceptible, reradiated noise from train vibration had an important influence on the building construction.

[1] Architecural drawing from Ignite Architects
[2] Photo from Mark Scowen

3. DESIGN CRITERIA

3.1 Background noise criteria

When filming, sound stages require a low background noise to ensure the sound recordings are not affected. A noise criterion on NC 25 during filming was specified as part of the brief. The design brief also indicated that internal noise sources within the site or non-frequent sources (freight trains, ambulance, etc.) would not need to be considered as part of the design.

The Noise Criteria descriptor (NC) is typically used to set a background noise criterion of room from relatively constant noise sources (e.g. mechanical services noise). However, it appears that this descriptor is commonly used in the design of sound stages. In accordance with the measurement standard, ANSI/ASA S12.2-2019 [1], noise is 'averaged' over the room during a measurement period of not less than 20 seconds.

Noise from train pass-bys can be of a short duration and if an average level descriptor, like NC, was to be used, the design criterion could be achieved but noise ingress might not meet the client's expectation. Discussions on the meaning and intent of the NC design criterion specified in the brief and the perception of short duration noise levels were important aspects to ensuring the design would meet the client's expectations. The use of percentile descriptors to communicate the transient nature of the noise sources was investigated, but these can be complicated to understand for non-acousticians. An auralisation of the predicted noise from train pass bys as well as typical background noise levels in the sound stage was undertaken in Marshall Day Acoustics' Listening Room [2]. This process, which is discussed later in this document, played an important in explaining the potential impact of train noise intrusion, enabled the client to fully participate in the decision-making process and gave them assurance about the outcome of the project.

3.2 Vibration criteria

Vibration from HVAC plant and trains also needs to be considered. While not part of the brief, the ASHRAE human comfort criteria was used and a design criteria of 0.14 mm/s was used for 'typical' trains with some minor exceedance of 0.2 mm/s allowed for 'worst-case' trains.

A vibration level of 0.1 mm/s is the limit of perception when placing hands on the floor and are concentrating in a quiet environment, this is 'operating theatre' level. A criterion of 'night-time residential' 0.14 mm/s would mean that vibration would generally not be perceivable during general activities.

4. BUILDING DESIGN

Sound stages' buildings require constructions that provide high levels of sound insulation. The use of precast concrete walls is very frequent in sound stages due to structural durability and sound insulation performance.

Concrete is effective at stopping airborne noise but is unfortunately efficient at radiating ground borne vibration. With building located near the train line, the use of concrete walls would have resulted in a large area of efficiently radiating concrete exposed within the studio. Based on the vibration levels measured, averaged noise levels of NC 23-29 were predicted from reradiated noise. This meant that investigating the use of alternative materials that are less efficient at reradiating ground borne vibration was required.

The design and construction program were only 22 months. This meant that an early contractor involvement was an important aspect in the design. While the design concept was developed early in the design, the exact construction materials were adjusted in close collaboration between all design team members and selected contractor to ensure all requirements were achieved: acoustic performance, procurement times, cost, etc. The design process and solutions proposed are described in the next sections.

4.1 Building constructions to control noise ingress and reradiated noise

4.1.1 External walls

High levels of sound insulation can be provided by either very heavy masonry constructions or from multiple skins of lighter weight materials. As regenerated noise from train vibration with concrete walls was identified early in the design, a double skin facade system spaced by a large cavity and isolated between layers was proposed.

Materials like Korok and Durra panels (see Figure 4) are less efficient at reradiating ground borne vibration and are commonly used in large buildings in New Zealand due to its long spans and quick installation. Durra panels are made of compressed wheat straw, which is a natural and renewable resource. Korok panels are made of a galvanised steel shell with an aerated concrete infill.

Figure 4. Image of Durra panel (left) Korok (right)

The construction below was recommended (see the architectural detail in Figure 5).

- Steel profile cladding on a 45mm ventilated cavity with battens at 1200mm centres
- 78 mm Korok panels
- 500mm cavity with a lightweight fibreglass/polyester blanket (90 mm thick and minimum density of 10 kg/m^3)
- Durra panel to the studios side

To maintain the sound insulation performance of the system it was important to maintain the isolation between the inner and outer layers. A robust and consistent solution, isolating the connection of the Korok panels to the main structure with neoprene pads, was designed between the authors and the architects to ensure this isolation was achieved throughout the building and reduce the risk of construction errors on site.

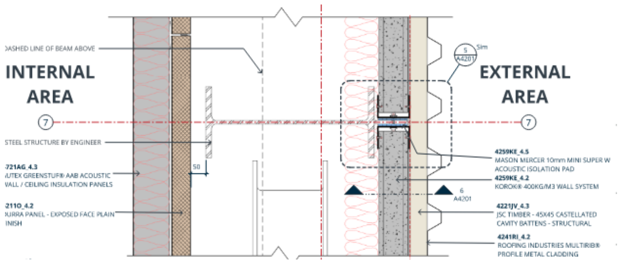

Figure 5. Image of external wall construction[3]

Figure 6 shows a comparison of the predicted sound insulation performance of the system proposed compared to a 200mm thick concrete wall.

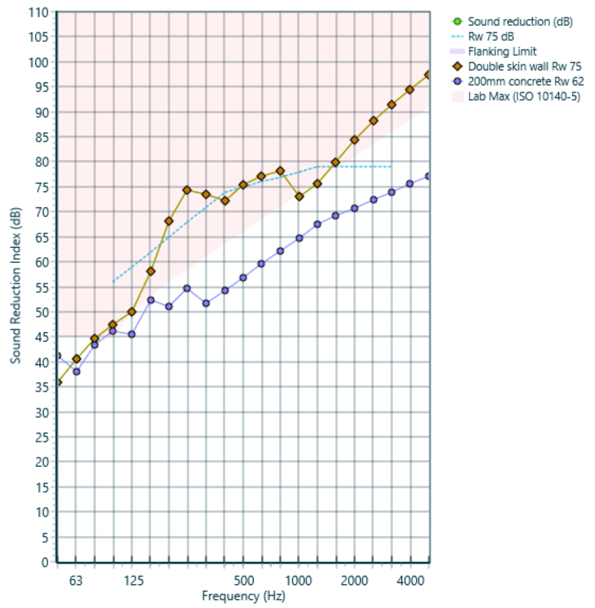

Figure 6. Comparison of sound insulation of concrete wall with double skin system in INSUL

As it can be seen in Figure 1, in one of the external walls, the Korok panel and external cladding had to be replaced with a concrete panel for fire reasons due to the close proximity of a building from another site to the sound stages.

4.1.2 Roof/ceiling

The roof/ceiling represents a very large area, and therefore the sound insulation performance was important too. Furthermore, rainfall is frequent all year round in Auckland with sporadic heavy falls. The client informed that rain noise is a limitation in other sound stages.

With the tight construction period and the roof construction planned for the winter period, the contractor's input in the roof systems to ensure building was weather tight as soon as possible was important. The design team worked collaboratively with the contractor to design a system based on this and met the acoustic performance required. The roof/ceiling system in Figure 7 was proposed, which addresses both noise ingress and controls rain noise.

[3] Architecural detail from Ignite Architects

- Steel warm roof system with a solid mass layer and stone wool core
- 400mm cavity with a lightweight fibreglass/polyester blanket (min 90mm thick and min density of 10 kg/m^3)
- Korok (600 kg/m^3) connected to the roof at no closer than 1200 mm centres

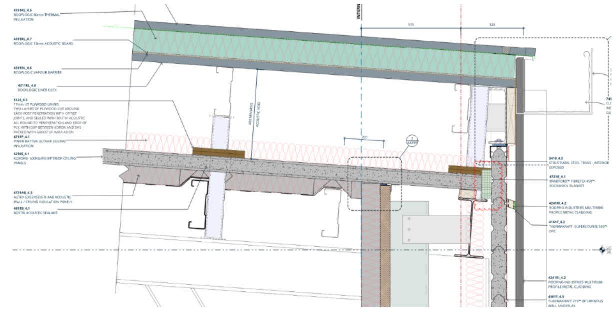

Figure 7. Roof/ceiling construction[3]

4.1.3 Scenery doors

Large scenery / elephant doors (7m x 7m) are required in sound stages for loading and unloading purposes. Doors are typically the weakest point in the sound insulation of a building, but their performance was key to achieving the design criteria.
Two sets of medium performance doors were initially discussed as the most robust solution. However, a single high performance scenery door (STC/R_w 55 and NIIC/D_w 58) was finally selected for cost reasons. Each studio has two of these doors.
The operational mechanism of the doors was an important aspect in the design. Sprinklers are typically not desired in sound stages because a false trigger could destroy the sets, which would have a significant cost implication. Large smoke extract fans connected to the AHU ductwork were used as the fire protection and smoke extract design. This meant that the doors need to be capable of opening quickly to provide enough make up air.

4.1.4 Slab

With the slab on grade, noise reradiated from train vibration through the slab and masonry upstand was predicted to range between NC $_{1sec}$ 23-28 during short periods of time but meet the design criterion of NC 25 when averaged according to the relevant measuring standards (ANSI/ASA S12.2-2019) in the studio closer to the train line.
An example of the noise levels predicted within the studio from the train vibration during a train pass-by with the slab on grade is shown in Figure 8. The approximated duration of the train pass by is 30 seconds. The graph shows the noise levels predicted for each second (NC_{1sec}) in blue, and the averaged noise level when measured/assessed according to ANSI/ASA S12.2-2019 is shown in red. While the averaged noise level for 20 seconds (minimum measurement length) would be NC 20-25, noise from trains would be higher than NC 25 during short periods of time, in this example 8 seconds.

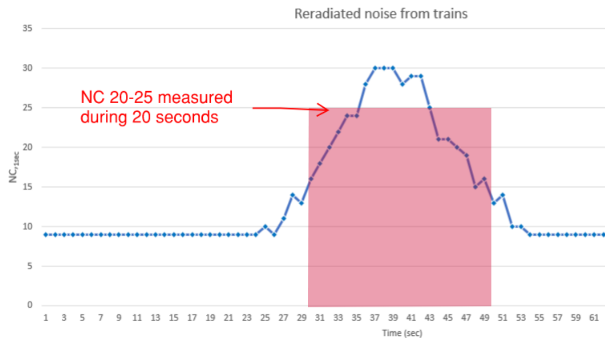

Figure 8. Noise from train pass by in sound stage closer to the train line with slab on grade

Up to approximately 12 trains per hour cross near the sound stages at times. Even though the design was predicted to meet the design criteria without further treatment, additional mitigation measures were explored to reduce the possible disruption from train pass bys: isolating the train tracks (this was not possible for practical reasons), trench along site (the trench to be effective this would need to be very deep, and it was found out this the trench was not possible because of the high water table on site) and isolating the slab of the sound stage.
Due to the elevated cost of isolating the slab, it was important for the client to understand the effects of the noise from the trains in the sound stages. An auralisation of the noise from train pass bys with and without the isolation was demonstrated in Marshall Day Acoustics' Listening Room. The demonstration was presented to representatives of the client. During the demonstration, sound engineers, who would be working in the studios, simultaneously recorded the background noise to verify if this would be disruptive in their recordings. The demonstration included a VR 3D model of the sound stage and sound was reproduced via a calibrated array of speakers providing an immersive as well as accurate experience (see Figure 9).

Figure 9. MDA's Listening Room

Following the demonstration the client decided that the isolation of the slab was required to achieve sufficient protection from train pass-bys.
The slab was isolated using a 50mm Sylomer mat (SR-11) below the entire slab (see Figure 10), which has a natural frequency of 21 Hz. Measurements showed that most of the vibration energy from passenger trains was around 125 Hz. With this design the noise from the trains was predicted to meet the design criteria and be well below NC_{1sec} 25. A minor increase in vibration was predicted at some low frequencies but this was predicted to still be generally imperceptible, only just noticed when lying down still and quietly.

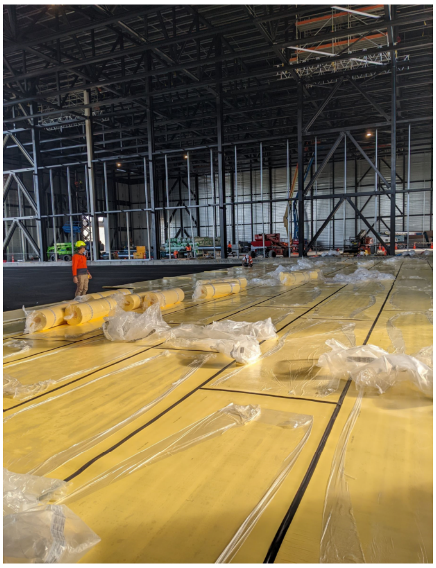

Figure 10. Sylomer mat during construction

4.2 Other design considerations

4.2.1 Sound insulation between studios

The Te Pūtahi building has two sound stages. Each sound stage could be used by a different client and therefore the sound insulation between sound stages needed to be considered.
A concrete wall, similar to other sound stages, was not appropriate due to the reradiated noise from trains. With the use of Durra panels to the internal walls of the building envelope, it seemed logical to use Durra panels for the internal wall. A double Durra panel wall including fibrecement layer with a large cavity and independent structures was proposed (see Figure 11).

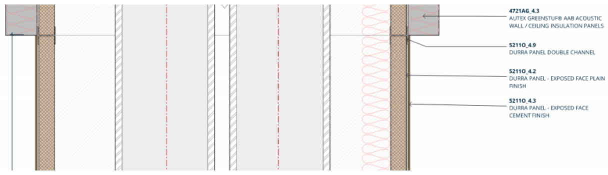

Figure 11. Wall construction between studios[4]

4.2.2 HVAC noise

The design team was informed that the low background noise from mechanical services is only required during critical recording and the mechanical systems would typically be turned off during filming. Nevertheless, the following design criteria for mechanical services noise was agreed for the different uses:

Table 1. Background noise criteria for different uses

Activity	Background noise criteria (NC)
Filming preparation with an occupied set and speech communication required	30-35
Scenery construction	35-40
Warehouse/workshop	40-45

Mechanical equipment is typically located in an outdoor plantroom and sections of internally lined ductwork and long attenuators are required to control noise from the HVAC equipment and noise ingress.

[4] Architecural detail from Ignite Architects

4.2.3 Rain noise and noise ingress via the ductwork

With the mechanical equipment located on an external plant platform, rainfall on the external ducts and external noise break-in into the ductwork after the attenuators can compromise the design, particularly in a high rainfall location like Auckland.

Acoustically it would be preferable to locate the attenuators at the penetration of the building envelope, but this was not practicable due to the space constrains. To mitigate the risk of rainfall and noise ingress, a flexible connection in the ductwork and a rain shroud, isolated and spaced away from the ductwork, between the attenuators and building penetrations was built (see Figure 12).

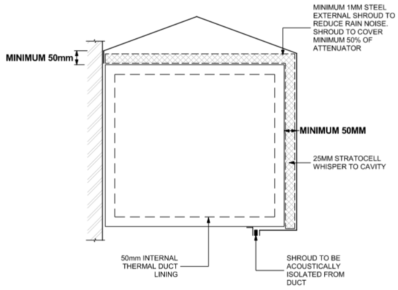

Figure 12. Rain shroud[4]

4.2.4 Absorptive treatment

It is important that sound stages are acoustically ‘dead’ spaces, and all available surfaces (ceiling and walls) are to be covered with absorptive materials. The lower section of the walls (<2m) is typically not covered with an absorptive material as a robust layer is desirable. This area will be normally obscured by sets during filming, treatment over this section of the wall is not normally required.

A black 100mm high density polyester blanket (density of 48 kg/m^3) was used on the walls and ceiling (see Figure 13).

Figure 13. Internal view of Te Pūtahi sound stages[5]

[5] Photo from Mark Scowen

5. COMMISSIONING RESULTS

Commissioning measurements were undertaken to confirm compliance with the design brief. These included measurements of the background noise from noise ingress and mechanical services at different operation modes, and the sound insulation performance of the doors. Overall, both sound stages perform very well and readily meet the design criteria.

5.1 Noise ingress

Background noise measurements from noise ingress were undertaken with a low noise microphone to ensure the floor noise of the microphone/sound level meter did not limit the measured performance. All HVAC systems were turned off during the measurements. Measurements were undertaken at a time with high train pass-bys to ensure a representative sample of noise sources was captured.

Studio 3 is the sound stage located at a further distance from the railway. The slab in this studio was not isolated as the rail line is located further away and the studio is shielded by studio 4 and other buildings. In this studio noise from trains was the most audible source. Averaged noise levels of NC 12-17 were measured from train pass bys with noise levels typically below $NC_{1,sec}$ 17, with the exception of an event where two trains (one each line) pass by during the measurements and noise levels raised of up to $NC_{1,sec}$ 22 (see Figure 14).

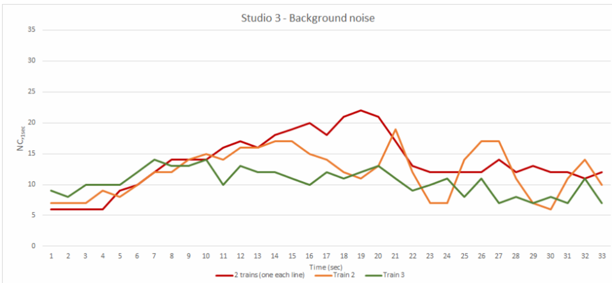

Figure 14. Background noise in sound stage non isolated (further away from train line)

In Studio 4, the isolated soundstage located near the rail line, train noise was barely audible above the background. An averaged noise levels of NC 15 was measured during train pass bys. As shown in Figure 15 (coloured solid lines), noise levels just barely exceeded $NC_{1,sec}$ 15 during some events. Noise from other noise sources (e.g. ambulance or loud motorbikes) were also below NC 20.

While studio 3 is the sound stage located at a further distance from the rail line, measurements show that noise from trains was higher in studio 4. This shows the importance of the reradiated sound from train vibration and effectiveness of the slab isolation.

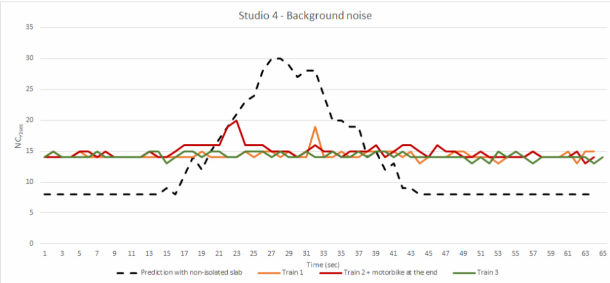

Figure 15. Background noise in sound stage with slab isolated compared with non-isolated prediction

Figure 15 shows a comparison of the noise levels measured in studio 4 (sound stage near the railway) and the predicted noise level from the reradiated noise without the slab isolated (dashed line in Figure 15).

5.2 Mechanical services noise

Noise from mechanical services noise was also measured for the different modes: air conditioning mode (mode with the AHU and fan set to maintain the temperature in the room) and boost mode (mode to cool/heat the sound stages).
The results of the measurements are shown in Table 2. These readily met the design performance recommended.

Table 2. HVAC background noise

Mode	Noise level (NC)
Air conditioning	20
Boost mode	25-26

6. ACKNOWLEDGMENTS

The authors would like to thank Auckland Tātaki Unlimited and Ignite Architects for their support on this paper and facilitating the architectural details shown. The authors would also like to acknowledge the teamwork and collaboration from the design team and contractors (Ignite Architects, eCubed, BGT Structures, Hayden + Rollet, Crossfire/Jensen Hughes, Precon and others) in a challenging but enjoyable project which has resulted in a very successful outcome.

7. REFERENCES

[1] ANSI/ASA S12.2-2019, *Criteria For Evaluating Room Noise*

[2] Marshall Day Acoustics Listening Room, https://marshallday.com/the-listening-room