ACOUSTICS AND LIGHT WEIGHT ROOF STRUCTURES
HYATT REGENCY PERTH CASE STUDY

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ABSTRACT

It is proposed to replace the existing light-weight roof structure at the Hyatt Regency Hotel, Perth. The roof covers atrium and lobby spaces and is nearing the end of its service life. A number of replacement systems are under consideration and Marshall Day Acoustics Pty Ltd was commissioned to review the proposed alternatives and provide guidance on the potential acoustic implications of each proposed alternative system.

The assessment included measurements of the existing acoustic conditions at the Hyatt Regency, Perth. The proposed alternative systems (Lexan, Danpalon and ETFE Cushion) were then reviewed in terms of each material's ability to control external noise ingress, absorb reverberant sound and dampen rain generated noise. Available acoustic performance data is not extensive, therefore the assessment has also relied heavily upon the review of the material properties and empirical calculations.

In summary, none of the proposed materials are anticipated to perform particularly well acoustically. Factors such as weight, constructability, maintenance and cost are likely to be the major determinants in the selection of the replacement material or system. As far as practicable the acoustic implications of one material over another is to be considered on the basis of at least maintaining the existing acoustic conditions. It is apparent that acoustics must be considered when designing light-weight roofing systems, particularly for acoustically sensitive spaces. For spaces with a high level of acoustic sensitivity, light-weight roof systems may not be appropriate and higher performance systems may be required.

1.0 INTRODUCTION

The Hyatt Regency Hotel is located at 99 Adelaide Terrace, Perth. Circulation to guest rooms is via internal balconies which overlook the large central atrium and four radial wings which are approximately nine storeys high and each covered by a light-weight polycarbonate roof system.

It is proposed to replace the existing light-weight roof structure that covers the reception, foyer, lobby and corridor spaces. It is proposed to replace the existing light-weight polycarbonate roof with an equivalent or alternative light-weight roofing system such as Lexan, Danpalon or ETFE. Marshall Day Acoustics Pty Ltd (MDA) was commissioned to assess each of the proposed options in terms of the following:

- External noise intrusion from roof mounted plant
- Rain noise
- Reverberation within the atrium

MDA undertook a number of acoustic measurements within the atrium spaces and reviewed the three proposed systems in terms of each material's ability to control the three factors noted above. The investigation involved reviewing limited published acoustic performance data, therefore the assessment also relied heavily on the review of the material properties and empirical calculations.

2.0 SITE DESCRIPTION

The atrium is surrounded by four service cores which house mechanical services plant and lift motor rooms at roof level. Ventilation louvres to the enclosed services cores face directly on to the polycarbonate roof.

Figure 1 shows the extent of the light-weight roof and the location of the services cores.

Figure 1: Roof view (source: nearmap.com)

Circulation to guest rooms is via balconies which overlook the large central atrium as shown in Figure 2.

Figure 2: Central atrium and balconies

The atrium houses reception, guest dining and lounge areas and a large fountain which provides significant ambient noise levels in the space and beneficial sound masking.

3.0 EXISTING ACOUSTIC CONDITIONS

Noise and reverberation time measurements were undertaken by MDA at the hotel to establish the existing acoustic conditions and determine the noise level of external plant at roof level, for use in the calculations.

3.1 Noise levels

Noise level measurements were conducted externally in the vicinity of each service core and in the circulation space directly below. Ambient noise levels were also undertaken in the atrium at lower levels to reduce the contribution of the mechanical services plant.

Table 1 details measured noise levels at each location.

Table 1: Measured noise levels, L_{eq} dBA

Location	Measured noise level, L_{eq} dBA
North core	
SEF ducts on roof	64
AHU intake	78
Level 9 balcony adjacent to SEF ducts	59
Level 9 balcony adjacent to AHU intake	58
South core	
SEF ducts on roof	61
AHU intake	78
Level 9 balcony adjacent to SEF ducts	59
Level 9 balcony adjacent to AHU intake	62
East core	
TEF discharge on roof	71
LMR intake	75
Level 9 balcony adjacent to TEF discharge	57
Level 9 balcony adjacent to LMR intake	58
West core	
KEF discharge on roof	78
LMR intake	75
Level 9 balcony adjacent to KEF discharge	57
Level 9 balcony adjacent to LMR intake	59
Level 7 away from plant (contribution from fountain)	62

Measured noise levels within the atrium are currently above the noise levels of 45-55dBA recommended by Australian Standard AS2107-2000 Acoustics - Recommended design sound levels and reverberation times for building interiors, for foyers and lobbies [1].

The ambient noise environment in the atrium is influenced by noise from the fountain and other guest and staff activity within the space. Therefore the noise level contribution of roof mounted plant is likely to be less than the measured levels, as indicated by the measurement on Level 7, which is primarily governed by noise from the fountain.

The measured noise levels indicate that the existing roof system is providing a frequency dependent noise reduction of approximately 15-20dB.

Given the levels measured in the balcony areas, it is anticipated that plant noise is unlikely to influence the acoustic environment within guest rooms.

3.2 Rain noise

We were unable to measure rain noise during our site visit. Hotel management indicated that rain noise is audible within the atrium but is not considered to be intrusive.

3.3 Reverberation time

Reverberation time measurements were conducted within the atrium. The measured reverberation time was 2.0-2.5s which is considered reasonable for such a large public space.

It was also subjectively considered that the reverberation time of the atrium is primarily driven by the volume. Additionally, the reverberation will vary greatly within the space depending on the proximity of semi-enclosed spaces and high ceilings. It is therefore believed that significant reductions in reverberation time are unlikely to be achieved without the introduction of significant areas of absorption.

4.0 LIGHT WEIGHT ROOF MATERIALS

The existing atrium roof is constructed from 4.5mm polycarbonate panels. The three alternative roof systems were evaluated against each parameter. The following provides a summary of each of the materials and their corresponding acoustic performance based on supplier information, previous MDA experience and empirical calculations.

Transmission loss is a measure of the sound insulation performance of a material, in other words, the ability of a particular material to block or reduce the transmission of sound from one space to another.

Absorption co-efficient is a measure of the ability of a particular material to absorb incident sound. Absorbed sound is transmitted through the material or dissipated as heat. The remainder of the incident sound is reflected therefore materials that readily reflect sound will typically provide poor sound absorption and vice versa.

4.1 Lexan

One proposal is to use 4.5mm thick Lexan panels as a replacement for the existing roof. The acoustic performance of the Lexan panels is considered to be equivalent to the existing roof.

Table 2 details the anticipated sound transmission loss and absorption performance. Sound transmission loss and sound absorption performance have been predicted using empirical methods based on the material mass and thickness.

Table 2: 4.5mm Lexan sound transmission loss and sound absorption co-efficient

	Octave band mid frequency							
Description	63	125	250	500	1k	2k	4k	Hz
Transmission loss (dB)	7	8	12	17	22	27	31	dB
Absorption co-efficient	-	0.59	0.47	0.36	0.15	0.09	0.07	Sa

The transmission loss performance detailed above is consistent with the measured performance of the existing roof system. The Lexan Panels have an inherent flexibility which was anticipated to marginally dampen rain noise.

4.2 Danpalon

Danpalon is a polycarbonate panel with cellular core structure with a proprietary panel locking system. The system under consideration consists of 16mm thick panels with 6 core walls (layers).

Danpalon have published Sound Transmission Loss test report No. 12156-764, dated 21 November 1994, prepared by Inchcape Testing Services [4]. The report details the results of sound transmission loss testing of a 16mm thick Danpalon panel.

Table 3 details the sound transmission loss and absorption performance. Report No. 12156-764 presented results in terms of 1/3 octave, which have been converted by the author to octave bands for simplicity.

Table 3: 16mm Danpalon sound transmission loss

	Octave band mid frequency							
Description	63	125	250	500	1k	2k	4k	Hz
Transmission loss (dB)	10	14	16	20	25	28	24	dB

The test results indicate that the sample tested achieved a STC 24. Another report prepared by Centre Des Formations Industrielles [4] quotes noise reductions of 20-22dBA.

The results also indicate that the low frequency performance of the Danpalon may be superior to Lexan. This is believed to be related to the size and stiffness of the test sample and care should be taken when using the material to control noise sources with significant low frequency content.

The sound absorption of Danpalon is anticipated to be equivalent to Lexan.

4.3 ETFE

Ethylene tetrafluoroethylene (ETFE) roof consists of numerous pneumatic panels. The panels are constructed from a light-weight, thin film with a surface mass of approximately $1kg/m^2$. Table 4 details the anticipated sound transmission loss and absorption performance.

Table 4: ETFE sound transmission loss and sound absorption co-efficient

	Octave band mid frequency							
Description	63	125	250	500	1k	2k	4k	Hz
Transmission loss (dB)	1	3	2	7	8	10	14	dB
Absorption co-efficient	-	0.59	0.47	0.36	0.15	0.09	0.07	Sa

In comparison to other proposed roof materials, the sound absorption of the ETFE roof appears to offer beneficial performance, however the majority of incident sound will be transmitted through the material.

The panels are highly inflated resulting in relatively hard, stiff membranes. On this basis, noise generated by rain impact is anticipated to be significant.

5.0 RAIN NOISE PREDICTIONS

Extensive laboratory data is available to assess the noise generated by rain noise impacting on roof systems including metal-deck (steel), fibrous cement and plywood roofing with various combinations of ceilings and insulation below. Established empirical prediction methods are also typically based on the above systems as detailed in reference [3].

Empirical prediction methods based on metal-deck roofs do not currently deal with the light-weight roofing materials and single layer systems. These methods may be developed at some time in the future.

Building Research Establishment (BRE) test report No. 220312 [2], entitled Measurement of rain noise on roof glazing, polycarbonate roofing and ETFE roofing, dated 24 November 2004 details laboratory measurements of noise generated by rain impacting on a number of light-weight roofing systems including, glass, polycarbonate and ETFE with and without rain suppressors.

The measured results were presented in terms of Sound Intensity Level which enables sound pressure levels to be predicted in spaces of known volume and reverberation time. The tested systems are detailed in Figure 3 below.

Test numbers	Construction details
L904-023	• 25mm thick polycarbonate sheet (Brett Martin - Marlon st longlife Fivewall) • 3.4kg/m^2 • 1.5m x 1.25m • Test element angle was 30°
L904-024	• 6-12-6.4 glazing (6 mm toughened glass, 12 mm air space, and 6.4 mm laminate glass) • 30.5 kg/m^2 • 1.5m x 1.25m • Test element angle was 30° • Artificial rainfall fell upon the side with the 6mm toughened glass
L904-025	• ETFE Pillow: 150 micron layer taped to a 50 micron layer, air gap (200 mm cushion dip), 150 micron layer. • Air pressure: 180Pa • 2.23m x 1.6m • Test element angle was 30°
L904-026	• ETFE Pillow: 150 micron layer taped to a 50 micron layer, air gap (200 mm cushion dip), 150 micron layer. • Air pressure: 180Pa • 2.23m x 1.6m • Texlon rain suppressor Type 1 (Patent No. GB2387395A - Vector Special Projects Ltd) • Test element angle was 30°
L904-027	• ETFE Pillow: 150 micron layer taped to a 50 micron layer, air gap (200 mm cushion dip), 150 micron layer. • Air pressure: 180Pa • Texlon rain suppressor Type 2 (Patent No. GB2387395A - Vector Special Projects Ltd) • Test element angle was 30°

Figure 3: Test configurations (extract from BRE test report No.220312 [1])

Figure 4 details the measured intensity level below each of the tested systems

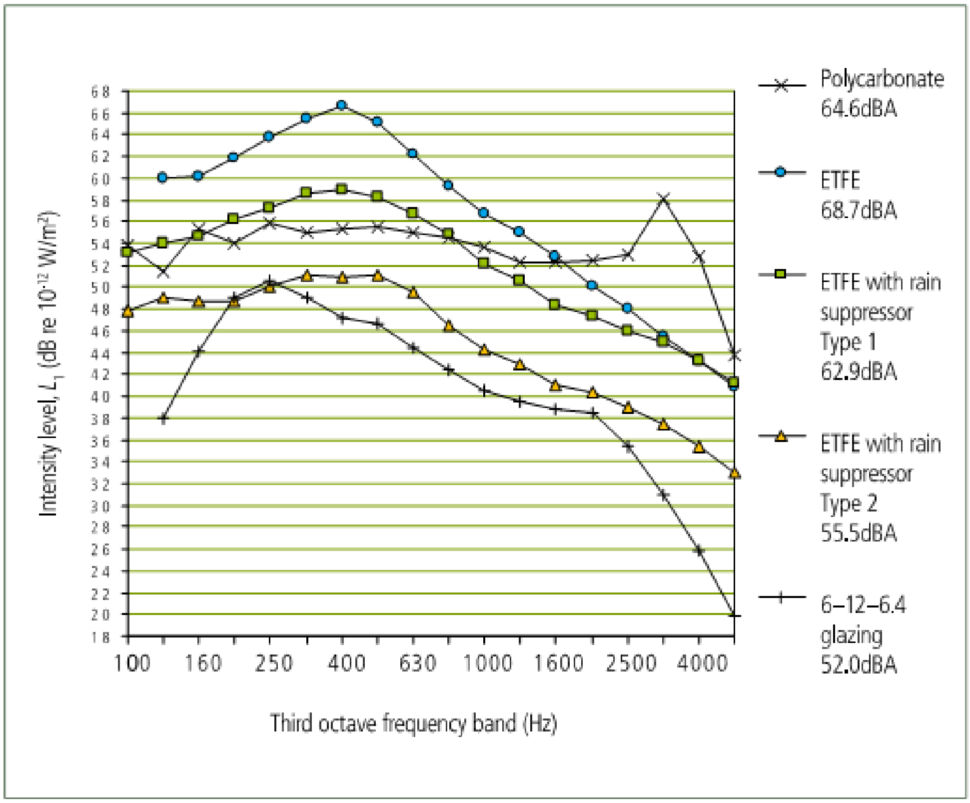

Figure 4: Measured sound intensity levels (extract from BRE test report No.220312 [1])

The tests confirm the assumption in Section 5: ETFE is predicted to result in higher rain noise levels in the hotel atrium space than with polycarbonate roofing. This is believed to be due to the relative stiffness of the ETFE cushion compared with the inherent flexibility of the polycarbonate roofing.

The exact make-up of the Type 1 rain suppressor has not been confirmed. An ETFE supplier has indicated that it is no longer available but was most likely a double layer of ETFE with an air gap.

The Type 2 rain suppressor is understood to consist of a mesh laid over the cushion which traps water to create a meniscus. The incident rain drops therefore land on the meniscus rather than the hard ETFE cushion.

As shown in Figure 2, the installation of rain suppressor Type 1 would reduce rain noise to a level roughly equivalent to polycarbonate. Further significant reductions up to 10dB can be achieved with rain suppressor Type 2.

6.0 SUMMARY

All of the proposed materials offer relatively poor acoustic performance in terms of sound insulation, rain noise control and sound absorption. However, the intention of the study was to maintain the status-quo as a minimum. The following summarises each of the proposed materials in terms of acoustic performance.

6.1 Control of plant noise break-in

It is understood that the noise in circulation spaces due to plant noise break-in is currently considered acceptable.

Figure 5 provides a comparison of the sound transmission loss performance of each of the proposed roof materials.

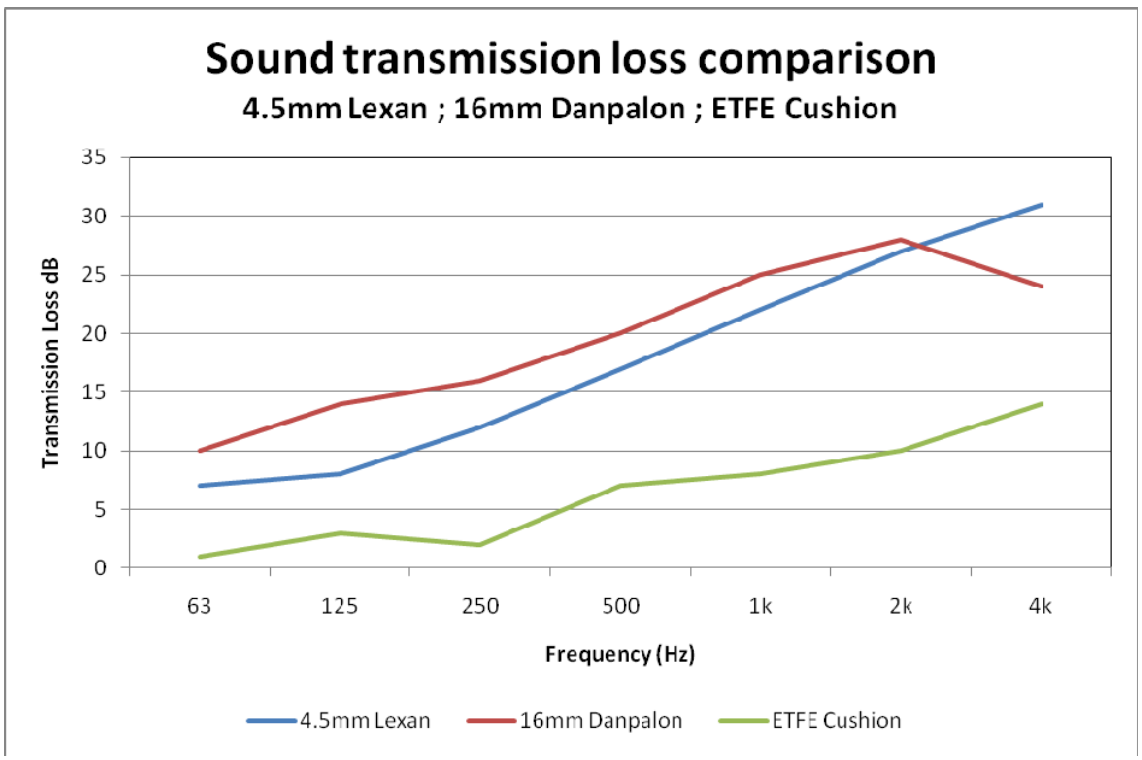

Figure 5: Sound insulation performance of roof materials

Suppliers test data and predictions of transmission loss performance indicate that the proposed Lexan and Danpalon systems are likely to control noise break-in to approximately the same extent as the existing roof. Plant noise levels in the atrium and circulation spaces are not predicted to significantly increase above existing levels.

The ETFE panels provide minimal sound transmission loss performance and it is anticipated that existing noise level contributions in the atrium and circulation spaces, due to plant noise break-in, may increase by up to 10dB, which is subjectively a doubling of the loudness. However, it is anticipated that the overall noise level in the space may not increase as initially expected due to the significant contribution of the fountain to the ambient noise environment within the atrium and balconies.

Although the sound transmission loss performance of the ETFE panels is estimated to be below that of Lexan and Danpalon, it may be considered economical to install ETFE panels and address plant noise levels through localised treatments such as acoustic louvres and screens where required.

Given the measured and predicted noise levels within the atrium and circulation spaces, it is anticipated that the noise level within guest rooms is unlikely to increase following the installation of any of these alternatives.

6.2 Rain noise control

It is understood that rain noise is currently audible within the atrium, however the level of noise is not considered to be intrusive.

The Lexan polycarbonate material is inherently flexible and will absorb rain noise impact to a marginal extent. The Danpalon material is expected to be similar in performance to Lexan.

The ETFE panels are inflated resulting in a very hard and stiff membrane. On this basis, it is anticipated that noise due to the impact of rain on the roof will increase above existing levels without the inclusion of a rain suppressor, Type 2.

6.3 Reverberation time

It is understood that the existing reverberation time within the space is considered acceptable and is anticipated to be primarily a function of the volume of the space.

All of the proposed materials can be considered acoustically reflective, approximately similar to the existing roof material. The ETFE panels may offer improved sound absorptive performance on the basis that a significant proportion of the incident sound energy is transmitted through the material.

Given the atrium volume, it is anticipated that all three materials will provide a similar result in terms of reverberation time. Minor local reductions in the reverberation time may be achieved with the inclusion of large areas of additional sound absorption within the space. However, due to limited available area for treatment, this would most likely need to be in the form of suspended banners.

7.0 CONCLUSIONS

Our review of the proposed materials indicates that the Lexan and Danpalon panel will be similar in terms of the control of external noise break-in, rain noise control and reverberation time. On this basis, the existing acoustic environment is anticipated to remain relatively unchanged.

It is anticipated that installation of ETFE panels may result in increased levels of noise from plant and rain impact within the atrium and circulation spaces. Given the construction benefits of using ETFE panels, it may be considered economical to address plant noise break-in by installing localised noise control treatment to plant and including a rain suppressor in the system. The need for additional treatment could be assessed following the installation of the roof.

References

[1] Australian Standard AS2107-2000 Acoustics - Recommended design sound levels and reverberation times for building interiors, for foyers and lobbies.

[2] Building Research Establishment Ltd (BRE)., Test Report No. 220312, Measurement of Rain Noise on Roof Glazing, Polycarbonate Roofing and ETFE roofing. Prepared for DfES 24 November 2004.

[3] Ballagh, K.O., Noise of Simulated Rainfall on Roofs, Applied Acoustics 31 (1990) 245-264, 28 February 1990.

[4] Inchcape Testing Services., Test Report No. 12156-764, Sound Transmission Loss (Danpalon 16mm Multicell), dated 21 November 1994. (source www.danpalon.com.au)

[5] Centres Des Formations Industrielles, Site Andresy., Report on Acoustic Measurements of Covering Elements in Polycarbonate.