# Aircraft noise intrusion: a practical study of glazing performance under high aircraft noise conditions for residential developments

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## ABSTRACT

The introduction of a third runway at Sydney's Kingsford Smith Airport and the increased pressure to develop inner city land for residential purposes has resulted in residential development in areas which would usually be considered unsuitable. Recent measurements were conducted at a development located under the flight path which required a glazing specification usually reserved for high performance commercial applications, such as recording studios. This paper examines the requirements of Australian Standard AS2021, the predicted versus the actual onsite glazing performance and the onsite conditions limiting glazing performance.

## INTRODUCTION

The introduction of the third runway at Sydney's Kingsford Smith Airport has led to a significant increase in the number of residential dwellings subject to high levels of aircraft noise. Many of these dwellings are sited within an Australian Noise Exposure Forecast (ANEF) zone of ANEF 25 or higher which is considered *unacceptable* by Australian Standard AS2021-2000 *Acoustics – Aircraft noise intrusion – Building siting and construction*.

Many new residential development proposals located in areas deemed *unacceptable* by AS2021 have been approved by the relevant authorities as these sites are located within existing residential areas.

A recent residential development project located in a residentially zoned area was situated between the ANEF 30 and ANEF 35 contour, which, in accordance with AS2021, is clearly within the *unacceptable* zone for residential development. The local authority required that the development comply with the provisions of AS2021.

The initial review of the site requirements under AS2021 was conducted by another consultant during the development application phase. The construction then began but was abandoned due to the developer filing for bankruptcy. At this stage the glazing had been approved by the local authority and the external glass and frames had been installed. It should be noted that heritage issues determined that the external glazing had to be timber vertical sash windows.

The project was then taken over by a financial institution to complete. The project manager engaged Marshall Day Acoustics to review the current status of the project and advise on what treatment was required to bring it to its completion.

Rather than conduct a complete re-design of the project and implement those design changes it was decided to engage in an iterative design process that allowed the level of improvement and additional treatment required to be ascertained at each stage

AS2021 sets out a calculation method to derive an Aircraft Noise Attenuation ($ANA_c$) for each component of the construction in order to achieve the recommended internal noise levels. AS2021 suggests that the $ANA_c$ be approximately equal to $R_w$ -5. However, where ANR values of greater than 30 are required the assessment should be conducted on an octave band basis. The original consultant had given a minimum sound transmission class for the glazing assembly.

## PROJECT DESCRIPTION

### Description of site

The development site was a multi-dwelling warehouse refurbishment and is located approximately 2.8km from the end of the north-south runway and almost directly under the flight path.

According to the aircraft noise level tables, AS2021 suggests that the site would be subject to aircraft noise as high as

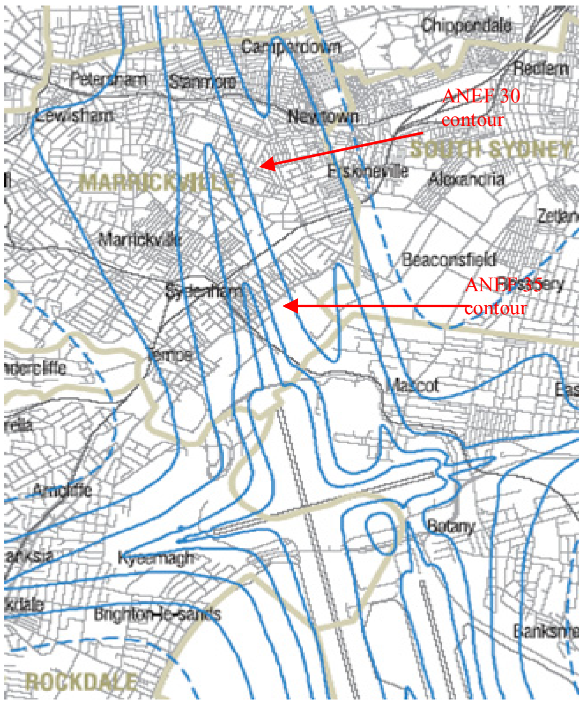



Figure 1 details the 2023/24 ANEF contours for the Kingsford Smith Airport in Sydney.

94dBA. As AS2021 requires that the indoor design sound levels from aircraft fly-overs be 50dBA within bedrooms, an Aircraft Noise Reduction (ANR) of 44dBA is required for bedrooms. As the construction was masonry with large areas of glazing, the major noise path would be via the glazing.

AS2021 states the following, regarding measuring noise levels onsite:

> If the ANR achieved is more than 5dB(A) below the design ANR, the envelope building components should be carefully examined to determine if they have constructed strictly in accordance with the specifications.

This can be interpreted as stating that it is acceptable for an onsite ANR to be within 5dBA of the design ANR. In this instance the ANR measured onsite must be greater than 39dBA

### Glazing requirements

In order to achieve an ANR greater than 39dBA, it was calculated that a minimum apparent weighted sound reduction index of 44dBA $R'_w$ must be achieved onsite.

The initial builder and their acoustic consultant had selected a glazing configuration with a laboratory performance of 48dBA $R_w$.

This configuration consisted of 10.38mm thick laminated glass and 6.38mm thick laminated glass separated by a 200mm airgap. The 6.38mm pane was part of the sash type external glazing and the 10.38mm pane was the internal sliding system. The 6.38mm pane was installed in a timber framed double hung sash window. The inner frame horizontal sliding aluminium sashes comprised of 2 or 3 sliding components.

## ITERATIVE TREATMENT PROCESS

### Initial results

Initial tests of the construction detailed above were undertaken on site. The test room had a glazed area of approximately 5m$^2$, resulting in an ANR of 34dBA which was significantly below what was expected.

For corner apartment bedrooms, where the overall glazed area was approximately 12m$^2$, it was estimated that an ANR of around 31dBA would be achieved.

During the testing it was noted that there appeared to be a mid-frequency component in the measurement spectrum which suggested that gaps were present. This was confirmed on removal of the internal plasterboard lining.

### After frame sealed

The glazing system for the initial test was then removed and replaced with a system of the same construction but with properly fitted seals and properly installed sliding mechanisms.

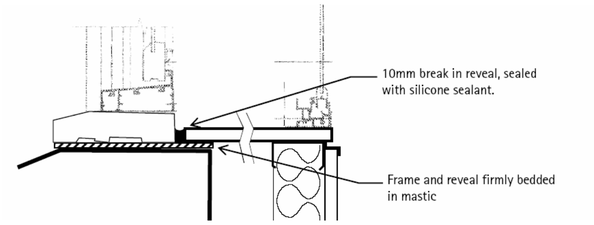
After the system was replaced, site measurements were again undertaken. These measurements indicated an improvement in performance of 5dBA (giving an ANR of 39dBA) within the test room (5m$^2$ of glazing).

The reconfigured system achieved the absolute minimum performance requirements for the test room, however, the apartment bedrooms located on the corners of the buildings with significantly greater glazing areas (12m$^2$) would fail by around 3dBA.

Figure 2 shows the extent of the gaps around the window frame.

### Silicone Joint

Upon closer inspection of the window reveal it was realised that the reveal did not incorporate a silicone joint.




Detail 1 illustrates the silicon joint in the reveal.

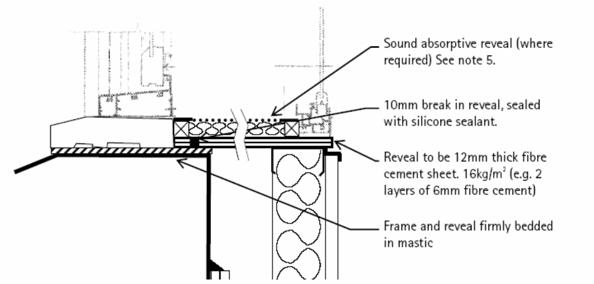
The incorporation of a saw cut and a silicone joint within the reveal provided a 2dB improvement in the ANR (ANR 41dBA). However, it was apparent that this construction still would not achieve the required performance for apartment bedrooms with the larger glazing area (12m$^2$).

At this stage of the investigation an airborne sound insulation measurement of the glazing was performed to compare with the laboratory results. The sound insulation testing was conducted in accordance with *ISO140 Part 5, Field measurements of sound insulation of façade elements and facades*. The measured performance of 42dBA $R'_{45E}$ is less than anticipated based on the laboratory result for the same system of 45dBA $R_w$.

The shortfall between the laboratory and the field results appeared to be due to sound flanking via the reveal and internal plasterboard layer.

### Absorptive reveal

As the final treatment, absorption was installed to the window reveals. This absorption was in the form of 25mm thick polyester insulation (30kg/m2) with a perforated facing with a minimum open area of 20%.




Detail 2 illustrates the absorptive reveal.

For the final treatment option the test room was changed to a corner bedroom with the larger area of glazing (12m$^2$) to confirm worst-case compliance.

A measured ANR of 43dBA within a corner bedroom indicated that the glazing configuration with the absorptive reveal would achieve the necessary performance. Taking into account the increased glazing area of the test room, it is estimated that the absorptive reveal increased the glazing performance by 4dBA. This improvement in performance matches that found in model studies (Cops et al 1975).

### Summary of improvements

Table 1 details the summary of improvements obtained at each step of the testing process.

| *Treatment* | Improvement |
|---|---|
| *None* | - |
| *Sealed Frame* | 5dBA |
| *Silicone joint in reveal* | 2dBA |
| *Absorptive reveal* | 4dBA |
| *Total* | 11dBA |

## VARIATION IN ANR BASED ON AIRCRAFT TYPE

### Onsite measurement variation

All the measurement results obtained were averaged over a number of plane fly-overs. The most common plane types during these fly-overs were the Boeing 747 and Boeing 767. Smaller 'prop' type planes were excluded from the investigation as the internal measured levels due to these planes were affected by background noise.

One point noted during the measurement process was that measured ANR values varied significantly based on plane type. It appeared that the primary reason for this variation was that the overall noise level for larger jumbo jets was dominated by noise at 250Hz, while the 767 overall level was dominated by 500Hz and 1kHz. Table 2 details measured external noise levels for a 747 during take-off and for the smaller 767 aircraft also during take-off.

Table 2 External Noise levels during take-off, $L_{max}$

| Plane Type | 63Hz | 125Hz | 250Hz | 500Hz | 1kHz | 2kHz | 4kHz | dBA |
|---|---|---|---|---|---|---|---|---|
| Boeing 747 | 97 | 102 | 102 | 96 | 92 | 89 | 80 | 98 |
| Boeing 767 | 78 | 79 | 81 | 82 | 79 | 76 | 74 | 84 |

Table 3 details the corresponding measured internal noise levels for each plane type. While the façade transmission loss and the room correction were identical for each test, the overall internal level was reduced by an additional 4dBA for the smaller plane type.

Table 3 Internal Noise levels during take-off, $L_{max}$

| Plane Type | 63Hz | 125Hz | 250Hz | 500Hz | 1kHz | 2kHz | 4kHz | dBA |
|---|---|---|---|---|---|---|---|---|
| Boeing 747 | 73 | 66 | 60 | 49 | 41 | 36 | 19 | 55 |
| Boeing 767 | 54 | 43 | 39 | 35 | 28 | 23 | 13 | 37 |

The resultant ANR values are 43dBA for the Boeing 747 and 47dBA for the Boeing 767.

### Variation in $ANA_c$ based on octave band analysis

Appendix G of AS2021 provides a prediction method for the $ANA_c$ based on spectral data for both the relevant aircraft noise and the sound reduction index of the component under consideration.

Based on the laboratory results for the glazing used onsite (which was provided by the manufacturer) and the measured spectral aircraft noise levels for Boeing 747s and 767s during takeoff, it was determined that the glazing provided an $ANA_c$ of 44dBA for Boeing 747's during takeoff and 47dBA for Boeing 767's during takeoff.

With a laboratory measurement of 48dBA $R_w$, it appears that the suggested $ANA_c$ . $R_w$ -5 is appropriate for larger aircraft which generate high noise levels but may cause the $R_w$ to be over-estimated for smaller aircraft which do not generate noise levels as high as 747's.

## SUMMARY

A recent residential development located in a high aircraft noise environment was required to meet the provisions of AS2021.

Earlier design and decisions meant that the project team was committed to a predetermined glazing configuration. The glazing configuration for the development consisted of a 10.38mm thick laminated pane of glass and a 6.38mm thick laminated pane of glass separated by a 200mm airgap.

Initial onsite testing revealed that glazing was underperforming. It appeared that the initial installation had not been appropriately supervised.

An iterative treatment approach to the remedial treatment of the glazing resulted in an appropriate level of sound insulation. Sealing the frame improved the glazing performance by 5dBA. Creating a silicone joint in the reveal provided an additional 2dBA and installing absorptive material in the reveal provided 4dBA, giving a total of 11dBA of improved performance.

It appears that there is some variation in the measured ANR based on the frequency component of the aircraft in question. This is supported by an octave band analysis based on appendix G of AS2021. This variation indicates that the 5dB correction between the $ANA_c$ and the $R_w$ may result in over-estimation of the required $R_w$ for smaller planes.

This also highlights the need to utilise and octave band assessment for sites subject to high levels of aircraft noise.

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