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MEASUREMENTS OF THE SOUND INSULATION OF HOUSES NEAR AUCKLAND INTERNATIONAL AIRPORT

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ABSTRACT
A series of aircraft sound insulation measurements has been conducted on nine houses in an area near Auckland International Airport with current noise levels of L_{dn} 61 to 63 dBA. Simultaneous indoor and outdoor measurements were analyzed in terms of A-weighted and spectral SEL data. Data was collected with windows closed and slightly open (100 mm gap). Houses constructed with various claddings, roofs and windows were selected. The purpose of the study was to determine the level of sound insulation achieved in New Zealand dwellings and to assist in the design of acoustic insulation of existing and future homes. The paper presents some of the results of the measurements and conclusions that can be drawn.

1 - INTRODUCTION
The aim of the project was to determine the extent of treatment that would be required for 10,700 houses within the projected L_{dn} 55 dBA airport noise contours (year 2030). A housing database was compiled, grouping houses into 10 types based on wall and roof cladding and window frame type. These houses near the airport are typically 2 or 3 bedroom, single storey dwellings, built with timber frames with cladding of timber (weather board), brick or fibre cement board. Internal lining is generally 9.5 mm gypsum plasterboard. Roof cladding is concrete or metal tile, or sheet metal. Thermal insulation in walls and ceilings has only been compulsory since 1978. Windows are typically 4 mm glazing in timber or aluminum frames.
The future external noise level (L_{dn}) was determined for each house from INM noise contours. 96% of the 10,700 houses are in areas with future levels less than L_{dn} 65 dBA. Noise measurements were conducted to determine the noise level <u>D</u>ifference from outdoor (<u>1</u>) to indoor (<u>2</u>), based on <u>a</u>ir <u>t</u>raffic and single <u>E</u>vents (note L_E = SEL), with the outdoor measurement at <u>2</u> meters from the facade: $D_{at,\ E\ 2m} = L_{E\ 1,\ 2m} - L_{E\ 2}$ [1].
Measurements were conducted at different locations within a bedroom of each house for a number of departures or arrivals of passenger jet aircraft. Some measurements were with windows closed, some were with windows open approximately 100 mm (ajar). External SEL were typically 85 to 95 dBA. Measurements have been <u>n</u>ormalized to 10 Sabines of absorption (10 m ^{2}), generally in accordance with ISO 140 [1], hence the term $D_{E\ 2m,\ n}$.

2 - A-WEIGHTED LEVEL DIFFERENCE
The measured overall A-weighted level difference $D_{A\ E\ 2m,\ n}$ with windows closed and ajar (hereafter, $D_{A\ closed}$ and $D_{A\ ajar}$, respectively) are summarized in Table 1, which is sorted in ascending $D_{A\ closed}$. Results with the windows closed have been standardized to an average window glazing area of 2 m^2 and the results with windows ajar have been standardized to an average open area of 0.3 m^2. The table includes an indication of the more important construction features.

Type	**External Wall Cladding**	**Window Frames**	**Roof Cladding**	**Aircraft Events**	$D_{A\ E\ 2m,\ n}$	
					Closed ($D_{A\ closed}$)	**Ajar ($D_{A\ ajar}$)**
2	Brick	Timber	Concrete tile	Arrive	20 dB	12 dB
3	Stucco	Timber	Concrete tile	Arrive	24 dB	16 dB
7	Brick	Timber	Sheet metal	Depart	26 dB	20 dB
2	Brick	Timber	Concrete tile	Depart	26 dB	20 dB
6	Timber	Timber	Sheet metal	Depart	29 dB	20 dB
7	Brick	Timber	Sheet metal	Arrive	30 dB	20 dB
1	Timber	Timber	Concrete tile	Depart	31 dB	15 dB
8	Fibre cement	Al	Metal tile	Arrive	31 dB	21 dB
4	Timber	Al	Concrete tile	Arrive	32 dB	17 dB
9	Brick	Al	Metal tile	Arrive	35dB	18 dB
5	Brick	Al	Concrete tile	not measured		
10	Plaster on Fibre Cement	Al	Metal tile	not measured		

Table 1: Measured overall $D_{A\ closed}$ and $D_{A\ ajar}$.

From the above results the following points can be noted:

- The $D_{A\ closed}$ results appear to fall into two clusters: 20 to 26 dB and 29 to 35 dB. (Also see Figure 1). There is no clear physical parameter that separates the two clusters, however we surmise that aluminum window frames and well sealed timber frames produce better results.
- The $D_{A\ ajar}$ results have a slightly smaller range or spread than the closed window results.

3 - SPECTRAL LEVEL DIFFERENCE

There are few clear trends for the above data, however, the spectral analysis proves slightly more informative. The octave band results for the Table 1 data, $D_{E\ 2m,\ n}$ (D_{closed} and D_{ajar}) are plotted in Figures 1 and 2, respectively, for nine houses. Note that the final column has the A-weighted data of Table 1. From the plots (and some other data not included here) we note the following points:

- The external spectra used (shown in Figure 3) include only large passenger jet aircraft and A-weighted levels are generally dominated by the 500, 1000 and 2000 Hz octave bands.
- Internal A-weighted levels are generally dominated by 500 Hz. In both Figures 1 and 2, it can be seen that the D_{closed} at 500 Hz is about the same as the A-weighted $D_{A\ closed}$.
- With windows closed, the two clusters − one higher, the other lower, performance − can be seen in Figure 1. The higher group includes all the houses with Aluminum window frames.
- As the internal noise levels and the A-weighted D_A are controlled by energy at 500 Hz, it appears that leakage at this frequency is important. Within the higher performance cluster, high frequency leakage varies greatly but is generally not the controlling factor.

4 - SOUND TRANSMISSION CALCULATIONS

To examine the calculated noise reduction versus the measured noise reduction (with windows closed), the sound transmission from an outdoor noise source to a reverberant space has been calculated for the 3 main partition elements, namely windows, walls and roof-ceiling. Transmission Loss (TL) data for the walls were based on the INSUL calculation program [2, 3] and data for roofs was from Cook [4]. TL data for windows was based on laboratory results with a leakage allowance for timber framed windows.

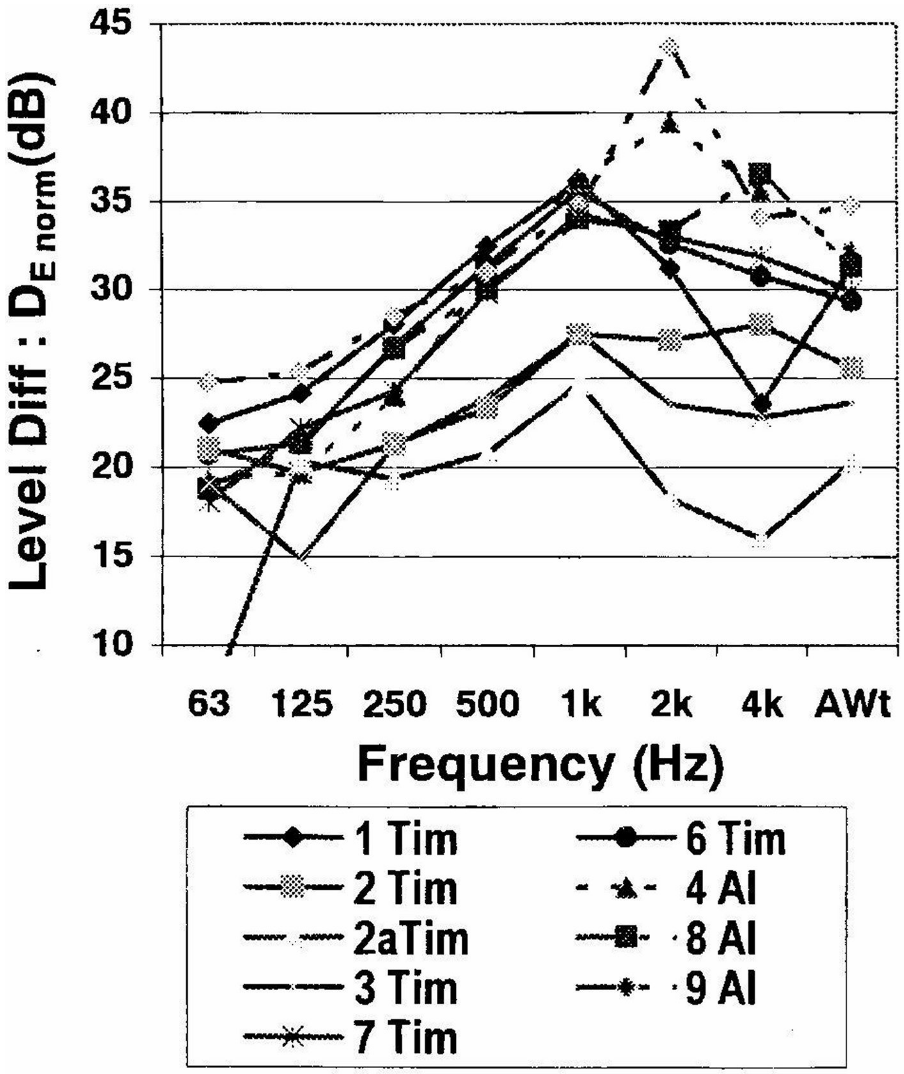

Figure 1: Windows closed (with Timber vs Al window frames).

The results are presented for 2 houses, Type 2 and 9, in Figures 3 and 4, respectively. Plotted are the A-weighted outdoor SEL (an average of about 50 measurements), the "measured" indoor spectrum (the average outdoor SEL − the measured average D_{closed}), and the calculated indoor spectrum with contributions shown from each the 3 main noise transmission paths. All spectra are A-weighted. From this analysis, the following results are noted:

- The calculated roof-ceiling path dominates the 63 and 125 Hz octave bands.
- The calculated window path dominates the bands at 500 Hz and higher.
- House 2 has timber window frames and the calculation has been used to determine the amount of leakage via the window frames. The glazing TL was derated so that the measured and calculated results (500 Hz and above) matched. There was found to be 9 dB leakage at 500 Hz, 10 dB at 1 kHz, 19 dB at 2 kHz and 15 dB at 4 kHz. This leakage accounts for the difference between the low and high performances in Figure 1.
- In Figure 4 for House 9, the measured D_{closed} at 63 Hz exceeds the calculated by almost 20 dB. At 125 Hz the difference is around 8 dB. This low frequency discrepancy was typical of all results except one − House 2 plotted in Figure 3 (see Figure 1 for the other low frequency results.)
- For House 9 with aluminum window frames, there is good agreement between calculations (not derated for leakage) and measurements at the critical 500 and 1000 Hz bands. There is also some 2 and 4 kHz leakage, although this has not degraded the A-weighted result.

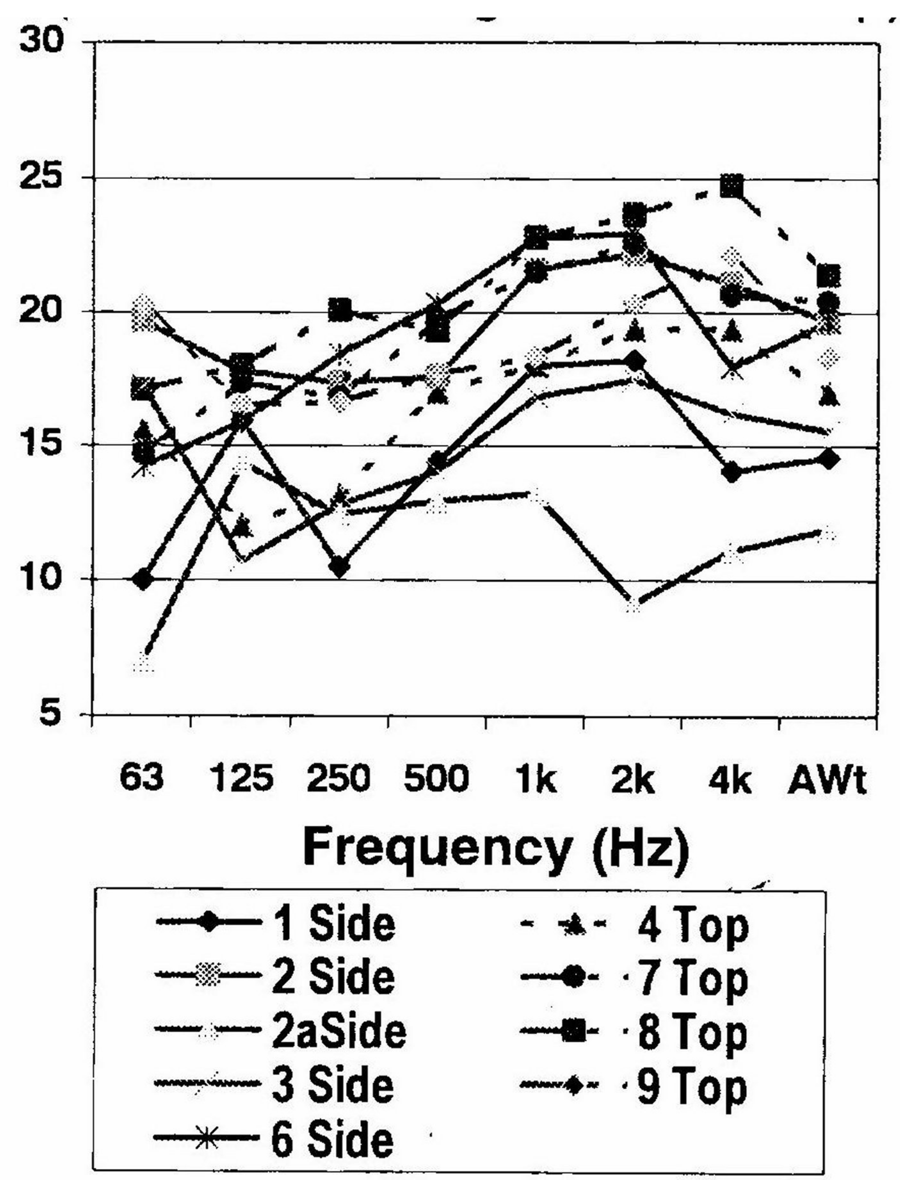

Figure 2: Windows Ajar (with window hinge - Side vs Top).

5 - CONCLUSIONS

- With windows closed, mid-frequency (and to a lesser extent high-frequency) leakage around the some timber window frame appears to be the most critical effect. In general, aluminum frames perform better than most timber window frames. Some timber frames appear to be well sealed and performing as well as aluminum frames.
- Laboratory and theoretical TL calculations can greatly underpredict the low frequency noise reduction measured on site. This is important for aircraft noise with spectra dominated by sub-250 Hz energy (eg Chapter 2 aircraft).
- Good agreement between measured and calculated results can be achieved for the mid and high frequencies.

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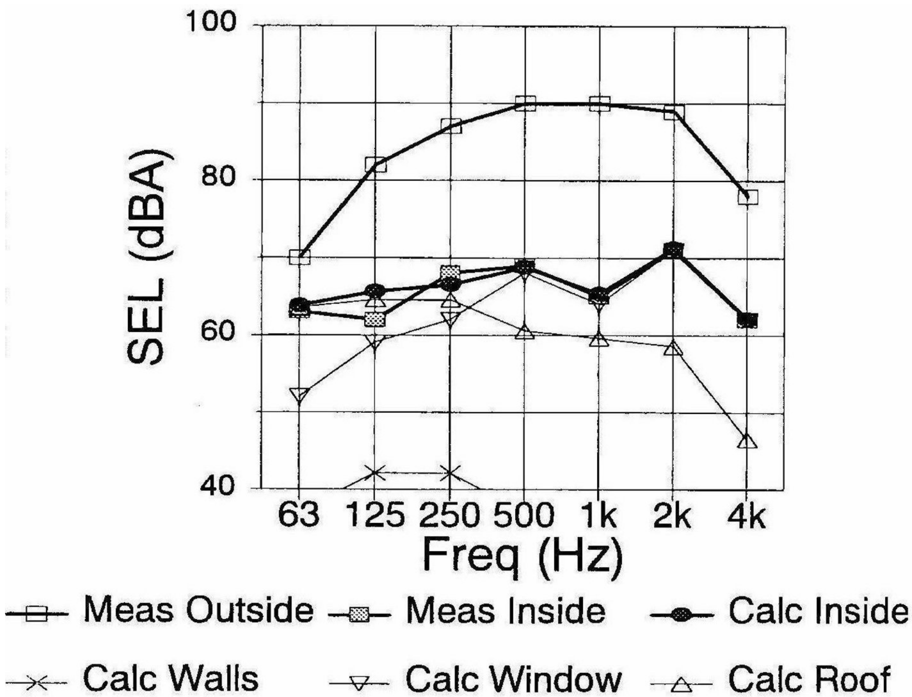

Figure 3: House 2; Brick/Timer WF/Conc tile roof.

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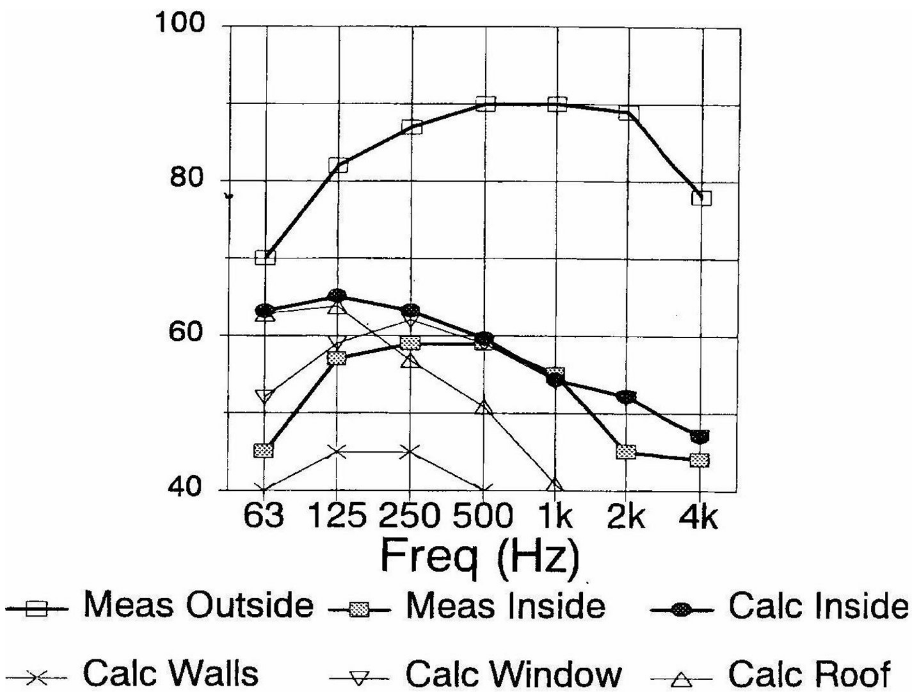

Figure 4: House 9; Brick/Al WF/Metal tile roof.