Acoustic Research Group
Department of Mechanical Engineering
University of Canterbury
Christchurch

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Road Traffic and Aircraft Noise Spectrums

Prepared by: Jeffrey Mahn

For: Peter Atkinson
Executive Officer
New Zealand Metal Roofing Manufacturers Inc.
Private Bag 92-066
Auckland 1142

Issued by: Dr J. Pearse
Mechanical Engineering Department
University of Canterbury
Private Bag 4800
Christchurch 8140
Ph: (+64) (3) 364-2987 ext 7252
Fax: (+64) (3) 364-2078
Email: jeffrey.mahn@canterbury.ac.nz

Summary

The frequency spectrum and the magnitude of road traffic noise are affected by the traffic flow rate, the speed of the vehicles, the road surface and the proportion of heavy vehicles to cars. Road traffic noise for vehicle speeds ≤ 50 km/hr includes a significant low frequency content due to noise from the engine and transmission which is perceived as being very annoying. There is also a peak in the spectrum around the 1000 Hz 1/3 octave band caused by the interaction of the tyres with the road surface. At higher vehicle speeds, higher frequency content due to noise radiated due to the interaction of the tyres on the road surface becomes more dominant than the low frequency noise.

Aircraft noise includes broadband low frequency noise due to jet noise. However, what is often found to be more annoying is the tonal, high frequency noise due to fan noise. There is significant difference in the magnitude and the frequency spectrum of aircraft noise when the aircraft is landing or taking off.

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1. Determination of the Sound Reduction Index of a Facade Element

The sound reduction index of an element of a building façade such as the roof of a house in the field is determined according to ISO 140-5:1998 [1]. The sound reduction index of a building element due to traffic noise, for example can be determined using either actual traffic noise if the noise is a minimum of 10 dB higher than the background noise level or using a loudspeaker which has been located to produce a particular angle of incidence (the preferred angle is 45 degrees). Using a loudspeaker source provides a much more controlled test with more repeatable results than using actual traffic noise [2].

During the measurement, the external noise level is measured with microphones positioned directly on the building element. The sound pressure level inside the receiving room is to be measured at multiple positions or with a rotating microphone. The sound reduction index of the building element when a loudspeaker noise source is used can be determined from [2]:

$$R'_s = L_{1,s} - L_2 + 10\log\left[\frac{S}{A}\right] - 1.5 \tag{1}$$

where $L_{1,s}$ is the average sound pressure level on the surface of the test specimen, L_2 is the average sound pressure level in the receiving room, S is the area of the test specimen and A is the equivalent sound absorption area in the receiving room.

If road traffic is used instead of a loudspeaker, the sound reduction index of the element is defined as:

$$R'_{tr,s} = L_{eq,1,s} - L_{eq,2} + 10\log\left[\frac{S}{A}\right] - 3 \tag{2}$$

where $L_{eq,1,s}$ is the average value of the equivalent continuous sound pressure level on the surface of the test specimen and $L_{eq,2}$ is the average value of the equivalent continuous sound pressure level in the receiving room.

Note that regardless of whether Eq (1) or Eq (2) is used, the level of the external noise source is that measured on the surface of the building element, not the level measured at the roadside. It is also important to note that the calculation of the sound reduction index of the element is not just a function of the sound pressure levels, but also the area of the building element under consideration and the sound absorption area in the receiving room.

2. Road Traffic Noise

The magnitude and the spectrum of road traffic noise depends on a number of factors including the traffic flow rate, the speed of the vehicles, the road surface and the proportion of heavy vehicles to cars [3]. Weather conditions have also been shown to have an effect on the spectrum and magnitude of road traffic noise [4].

The published literature includes a number of traffic noise spectra which have been measured in other countries, but these published spectra have been influenced by the road surfaces and the common makes and models of automobiles in the locations where the measurements were made. To make this study relevant to New Zealand, measurements of traffic noise which were made in New Zealand were provided as shown in Figure 1. The road traffic noise was measured at different locations and at different traffic flow rates as noted in the legend of the figure.

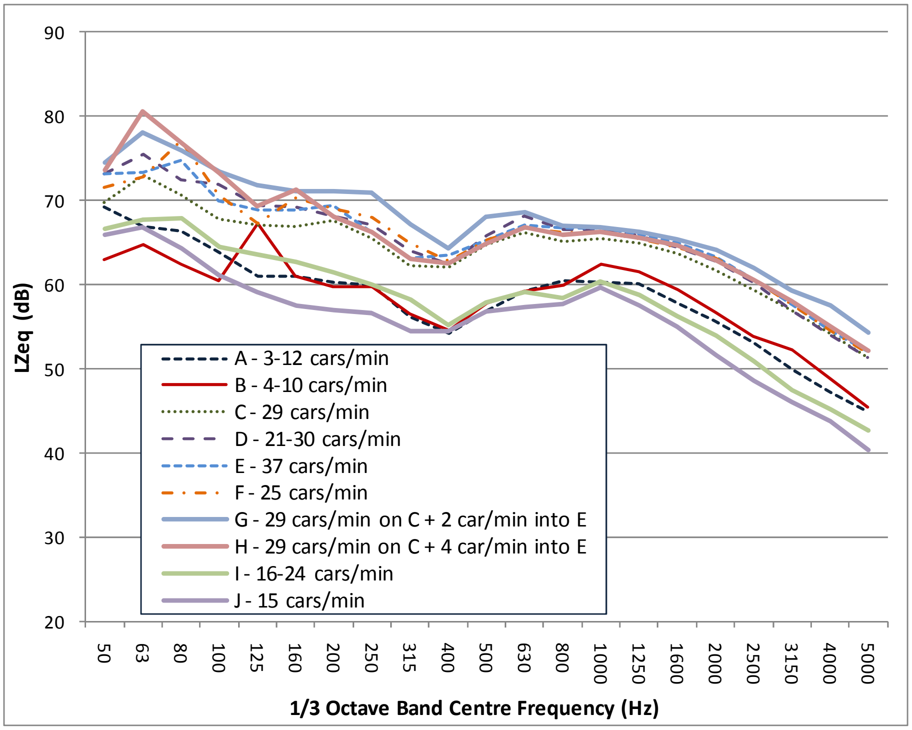

Figure 1: The equivalent sound pressure level of road traffic noise recorded in different measurement positions and at different traffic flow rates.

The LZeq shown in the figure is the equivalent sound pressure level with no frequency weighting. The figure shows the effect of traffic flow rate on the magnitude of the spectra with higher flow rates typically resulting in higher LZeq values. What wasn't recorded with the data shown in Figure 1 was the percent of heavy vehicles to cars or the average speed of the vehicles. Other studies have shown that the peaks in the spectrum shift to higher frequencies and that the sound pressure levels increase with increasing vehicle speeds [5].

The spectrums shown in the figure show large peaks at the low frequencies. This finding is in agreement with other studies [6, 7] which indicates that traffic noise can include a large amount of low frequency component. Killegreen [8] reviewed more than 2100 outdoor traffic noise spectra including the passage of more than 3.5 million vehicles and concluded that there is always a peak in the frequency range between the 50 and the 100 Hz 1/3 octave bands. Note that the low frequency peak coincides with the frequency bands where glass typically offers the least sound insulation [9]. The low frequency peaks are generated by the engine exhaust system and the transmission. The low frequency noise levels vary primarily according to engine speed rather than vehicle speed [10] and heavy vehicles contribute significantly to low frequency noise.

Figure 1 also shows peaks in the spectra around the 1250 Hz 1/3 octave band. These peaks are generated by the interaction of the tyres with the road surface [6] which is the dominant noise source under free flow traffic conditions at moderate to high road speeds [10].

Although Figure 1 shows the low frequency content due to the engine noise to be more dominant than the noise from the interaction of the tyres with the road surface, this is not always the case. In the case of urban traffic where vehicle speeds are low (≤ 50 km / hr) and vehicles are more frequently idling or accelerating, the vehicle engine noise is more dominant. In the case of highway traffic where vehicle speeds are relatively high, the dominant noise source is the tyre noise [11].

3. Aircraft Noise

Rosin and Barbo [12] have described the different components of the jet aircraft noise spectrum as shown in Figure 2.

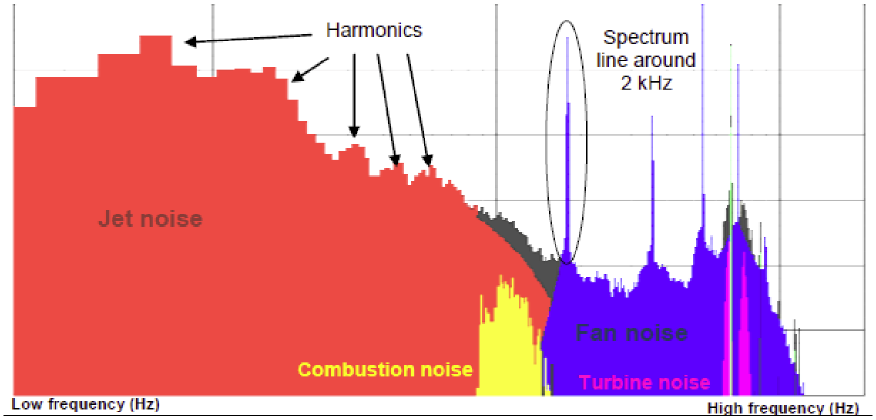

Figure 2: Sources of aircraft noise (Rosin and Barbo, 2010).

The spectrum shown in the figure includes a broadband, low frequency noise contribution from jet noise. Jet noise is generated primarily by the interaction of the high-velocity exhaust gasses with the relatively still air through which the aircraft passes [13]. As the gasses mix with the surrounding air, the resulting turbulence creates pressure fluctuations which radiate sound.

The figure also shows fan and turbine noise which occurs at the higher frequencies. The fan and turbine noise is highly directional with the noise from the compressor fans at the front of the engine creating high frequency tonal components. These tonal components embedded in the broadband noise can significantly affect the aircraft noise quality and increase the annoyance caused by the noise [14].

Typical noise spectrums for two families of aircraft are shown in Figure 3 and Figure 4.

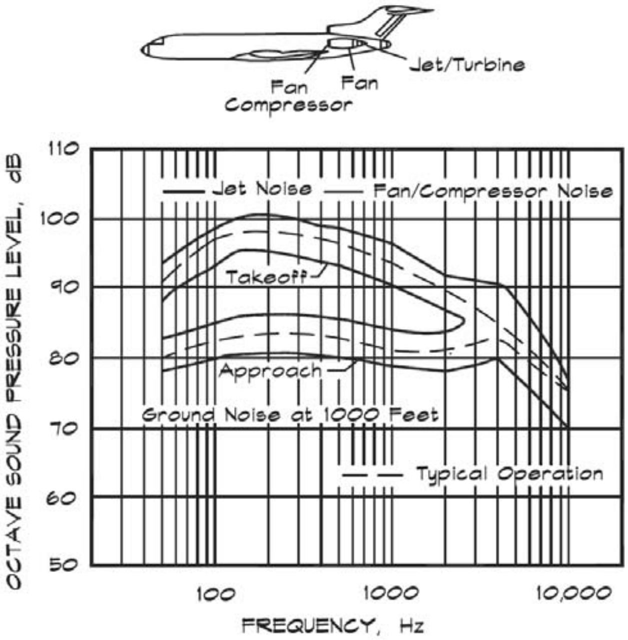

Figure 3: Noise spectra of a 2-3 engine low bypass ratio turbofan aircraft (Long, 2006)

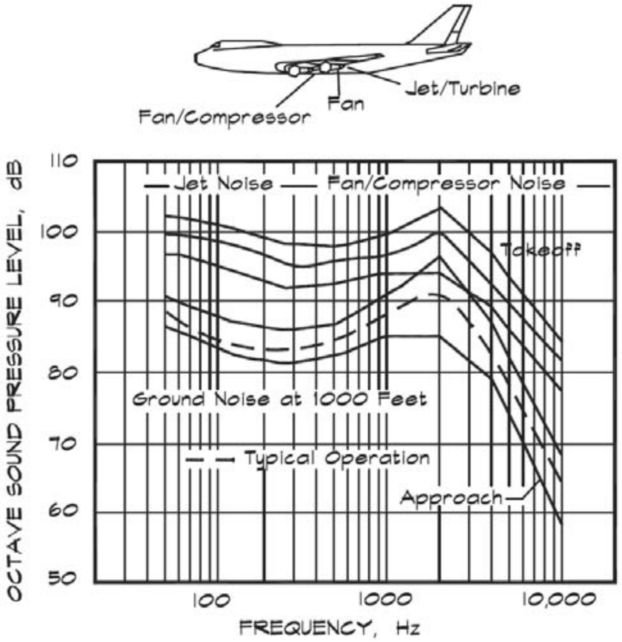

Figure 4: Noise spectra of a 4 engine high bypass ratio turbofan aircraft (Long, 2006)

The figures show that different aircraft will produce different noise spectrums. The noise levels are higher during takeoff and in the case of Figure 4 the peak around 1100 Hz is higher. The peaks in both figures around 1100 to 1300 Hz are due to the fan noise. There is significant low frequency noise on takeoff, but less so on approach.

Discussion

The urban road traffic noise spectrum included large peaks at the low frequencies. Noise with a high proportion of low-frequency components has been found to be perceived as more annoying than noise with mid to high frequency components [7, 15]. Therefore, the noise from the engine and transmission would be perceived as being more annoying than the noise of the interaction of tyres with the pavement.

Jet aircraft noise also includes a low frequency component. However, the low frequency component due to the jet noise would be perceived as being less annoying than the tonal components of the fan and turbine noise. Tonal components have been shown to have a great impact on noise annoyance, depending on the central frequency of the tone and its level [7]. However, aircraft noise is not always perceived as being the most annoying source of noise. In a study involving a sampling of residents who lived within 25 km of a large, international airport, Kroesen, et al. [16] found that aircraft noise was perceived as less annoying than noise due to slow road traffic (<50 km/h) or neighbour noise, but more annoying that noise due to fast road traffic noise (>50 km/h), railway noise, or construction noise.

An important factor to take into account when considering annoyance due to road traffic or aircraft noise is the rate of occurrence of the noise events and the time of day during which the events occur. A study by Jakovljevic et al. [15] found that the number of noise events by vehicles during night time and daytime correlates with annoyance. The study also found that the night time noise levels and the number of heavy vehicles at night were the most significant independent factors for a high level of noise annoyance.

A number of studies have been conducted regarding how to choose building elements to fit the environment in which a dwelling is to be built (for example see [17]). Typically, only the indoor noise limits are specified in the building code (see for example section G.6.3.4 of the proposed changes to Claus G6 of the New Zealand Building Code [18]). The weighted sound reduction index of the building facade is not specified in the proposed revisions to Clause G6. In some countries, the sound reduction index of the building façade is specified, but it is in terms of a single number rating. The significance of the low frequency peaks in the road traffic noise spectrum or the tonal components in the aircraft noise spectrum are lost due to the use of single number ratings when matching façade elements to the environment in which the dwelling is to be built.

Conclusions

Road traffic noise in an urban environment includes a significant low frequency component which can be found annoying. Although Jet aircraft noise also contains low frequency noise, it is the tonal components at the higher frequencies which are found to be most annoying. In both cases, the time and frequency of the noise events must also be considered when considering peoples annoyance due to the noise.

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