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INTERNATIONAL CONSULTANTS

DRIVE-BY VEHICLE NOISE

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Opus: *an accomplished work, a creation, an achievement*

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Contents

1 Introduction

A selection of road surfaces in the Hastings area was assessed to determine their influence on road traffic noise generation. The investigation was undertaken for Transit New Zealand. Some residents had claimed that certain types of road surface were "noisy".

2 Method of Assessment

On 23 November 1999, noise measurements were made of drive-by noise for a car as it travelled across several road surfaces, both in Hastings and Napier. Weather was fine, with a light southerly breeze. The road surface was dry.

The drive-by noise was measured as a series of single vehicle passes over the surfaces. Two individual sound level meters recording directly into a computer-based 1/3-octave band analysis programme were used to provide both overall noise level measurements, as well as data for spectral analysis.

Sound level meters used were:

- Rion NL-10; a type 1 integrating sound level meter;
- Quest 1900; a type 1 statistical sound level meter.

Both of these meters were fitted with an AC output, which was connected to the computer-based 1/3 octave band analysis programme for simultaneous logging and subsequent analysis.

The vehicle used was a 1997 Mitsubishi Lancer 1.6 GLXi sedan fitted with Dunlop "Monza 200" 185/65 SR14 tyres, inflated to 30 p.s.i. These tyres were showing little wear.

Vehicle drive-by passes were made in the lane nearest to the sound level meters. In all cases, distance from the sound level meter microphone to the left wheeltrack of the carriageway was 4.0 m. Vehicle speed was 50 km/h.

Texture depth of the road surface material was measured at each site, using the sand circle test method.

3 Assessment of Measurement System Consistency

Initial drive-by measurements were made with both sound level meters located first adjacent to the 1999 grade 2/4 chipseal (site 1), and then adjacent to the grade 3 chipseal site (site 4), so that any systematic errors due to differences in the individual sound level meters could be identified. Figures 1 and 2 shows the typical difference in frequency response between the two sound level meters. From this it can be seen that, particularly from 30 Hz, the instruments perform in a similar manner, and any difference is insignificant. Overall noise levels measured by each instrument for this drive-by were:

Site 1:	Rion NL – 10	77.5 dBA
	Quest 1900	77.4 dBA
Site 2:	Rion NL – 10	80.1 dBA
	Quest 1900	80.2 dBA

Figure 1: Standardisation of Instruments at Site 1.
Vehicle: Light car.

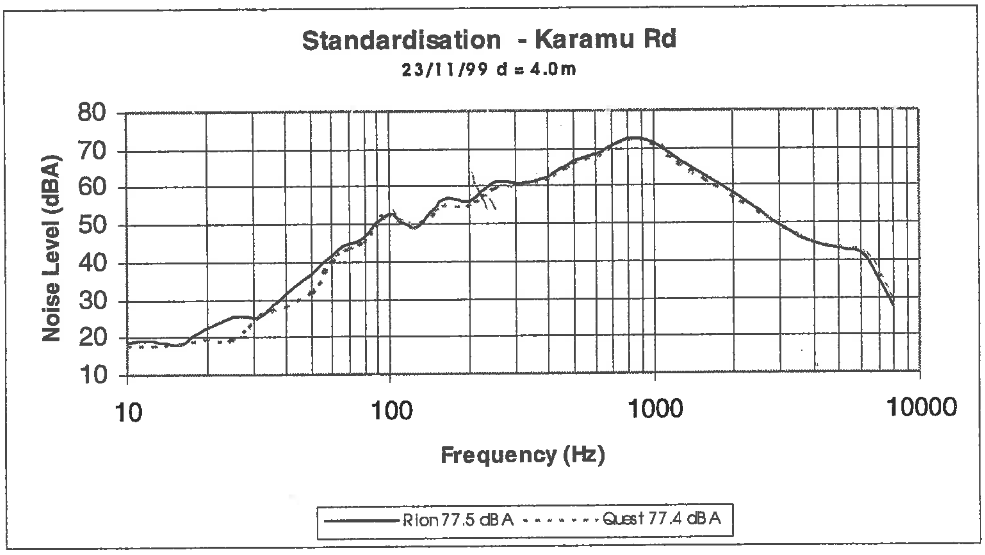
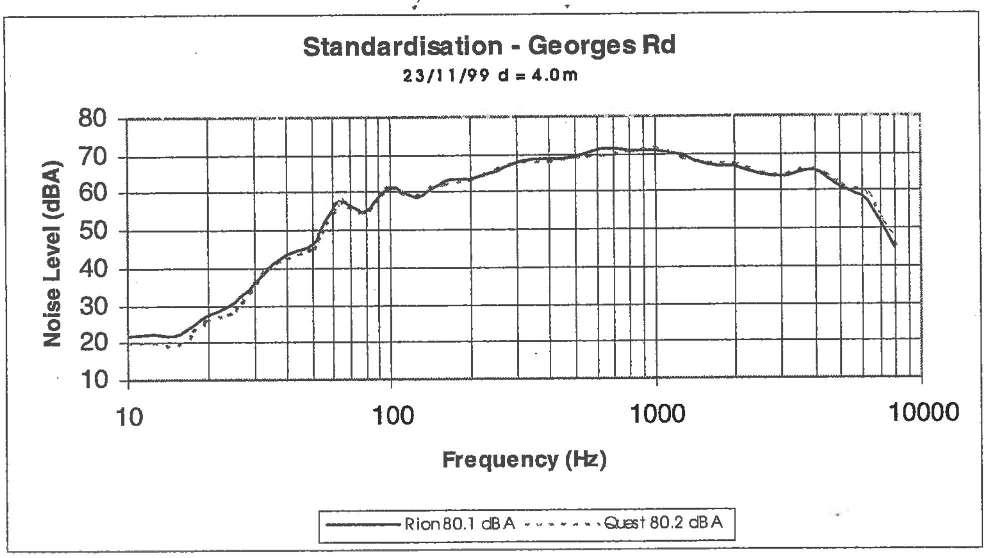


Figure 2: Standardisation of Instruments at Site 4.
Vehicle: Light Commercial Vehicle



4 Measurement Sites

Four separate sites involving six different seal types were studied. These were as follows:

Site 1: Karamu Road Hastings: RP 661/8.41

This site was adjacent to the seal joint between a grade 2/5 two coat chipseal almost four years of age, and a grade 2/4 two coat chipseal approximately 9 months old. Noise levels from vehicle drive-by runs on both surfaces in the northbound lane were studied and compared.

Site 2: Willow Park Road, Hastings

This location was adjacent to the Lyndon St intersection. The road surface was a mix 10 asphaltic concrete, approximately 5 months old. Measurements were made of vehicle drive-by noise on this surface in the southbound lane.

Site 3: Karamu Road north, Hastings: RP 661/9.4

The road surface at this location was a grade 3/5 racked–in chipseal, approximately 8 months of age. Measurements were made of vehicle drive-by noise on this surface in the northbound lane.

Site 4: SH 2, Georges Drive, Napier: RP 650/1.98

Two chipseal surfaces were studied at this location: a grade 3 single coat chipseal approximately 5½ years old, and a grade 2/4 two-coat chipseal, approximately 3½ years of age. Drive-by noise levels were recorded for the vehicle travelling in the northbound lane.

5 Results

5.1 Site 1 : Karamu Road

At this site, the Rion NL-10 sound level meter was placed adjacent to the newer grade 2/4 two-coat seal, and the Quest 1900 was placed adjacent to the older grade 2/5 two-coat seal. These sound level meters were set up at a distance of 4.0 m from the left wheeltrack of the carriageway. (Although a minimum distance of 5 m was preferable, this 4m distance was chosen to avoid reflections from a fence line that may have otherwise affected the readings).

Several vehicle drive-by passes were carried out, and overall noise levels for each of these runs are shown in Table 1.

Table 1: Overall Drive-by Noise Levels at Site 1

Run No	Drive-by Noise Levels (dBA)	
	1999 Grade 2/4	1996 Grade 2/5
1	73.9	72.4
2	74.1	72.8
3	74.7	73.1

From Table 1 it can be seen that drive-by noise levels recorded for the newer grade 2/4 surface are around 1.5 dBA higher than the levels recorded at the older grade 2/5 surface. Figure 3 shows that for the grade 2/4 surface, the most significant noise difference occurs between 150 Hz and 1 kHz (4 to 5 dBA). Although the noted differences in the lower frequency ranges (typically between 25 to 100 Hz) is large, at this stage their contribution to the overall levels is insignificant. It is also noted that from the 1 kHz point this trend is reversed, with the higher frequency noise being louder for the older grade 2/5 seal, with a difference of 5 to 8 dBA noted between 3 and 5 kHz

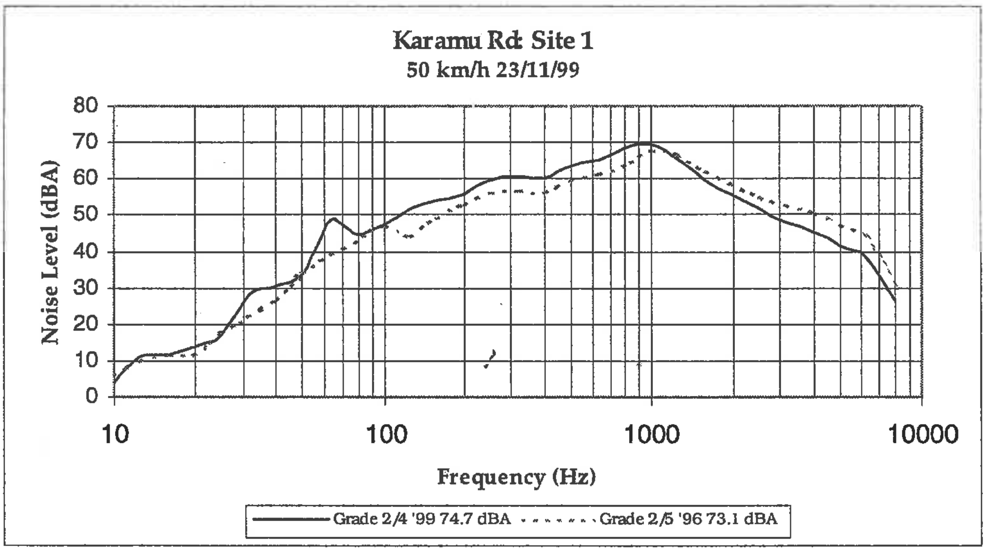


Figure 3: Typical ⅓octave band analyses of drive-by noise on the 1999 grade 2/4 and 1996 grade 2/5 surfaces at Site 1, Karamu Road Hastings.

It was noted that at this site, significant ground vibration was experienced each time a heavy vehicle passed.

5.2 Site 2 Willow Park Street

The road surface here is a mix 10 asphaltic concrete, approximately 5 months old.

The sound level meter microphones were located at a distance of 4.0 m from the left wheeltrack of the southbound lane.

Overall noise levels for individual vehicle passes measured at this site are shown in Table 2.

Table 2: Overall Drive-by Noise Levels at Site 2

Run No	Drive-by Noise Levels (dBA)
1	68.0
2	67.9
3	68.0
4	66.3

Figure 4 shows the typical frequency spectrum for dive-by noise on this surface.

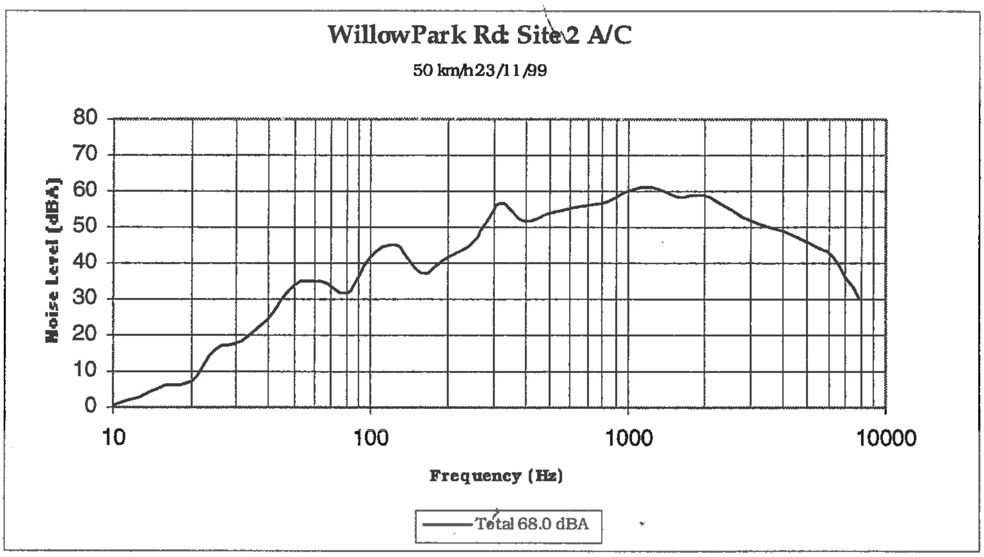


Figure 4: Typical ⅓octave band analysis of drive-by noise on the asphaltic concrete surface at Site 2, Willow Park Road Hastings

5.3 Site 3 Karamu Road North

The road surface here is a grade 3/5 two coat "racked–in" chipseal.

The sound level meter microphones were located at a distance of 4.0 m from the left wheeltrack of the northbound lane.

Table 3 shows the overall noise levels for individual vehicle drive-by passes measured at this site.

Table 3: Overall Drive-by Noise Levels at Site 3

Run No	Drive-by Noise Levels (dBA)
1	76.0
2	74.6
3	75.3

Figure 5 shows the typical frequency spectrum for drive-by vehicle noise recorded for this surface.

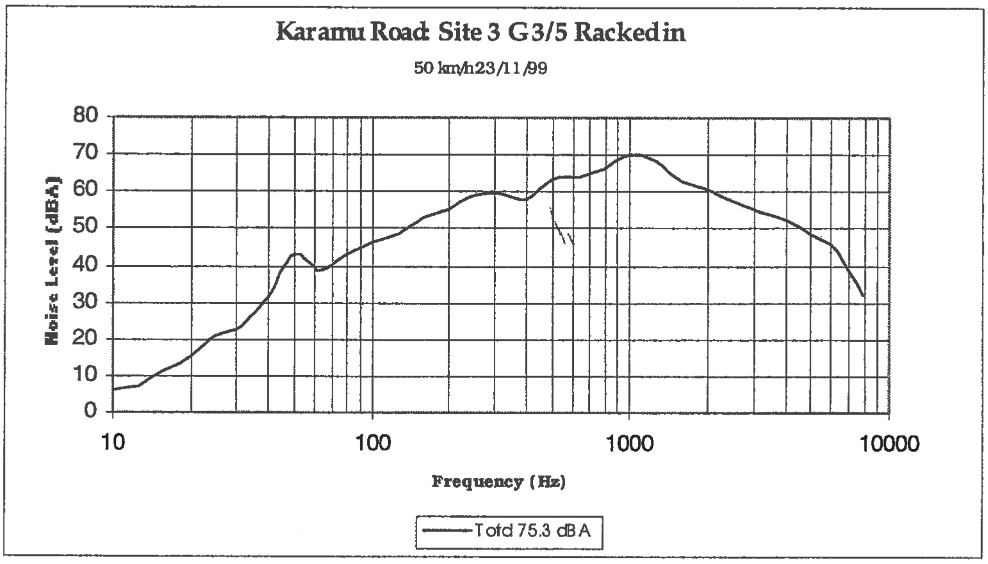


Figure 5: Typical ⅓octave band analysis of drive-by vehicle noise on the grade 3/5 surface at Site 3, Karamu Road North, Hastings

5.4 Site 4 Georges Drive, Napier

At this site, the Rion NL-10 sound level meter was placed adjacent to the grade 3 chipseal, and the Quest 1900 sound level meter was placed adjacent to the grade 2/4 two-coat seal.

The sound level meters were set up at a distance of 4.0 m from the left wheeltrack of the northbound lane.

Two vehicle drive-by passes were carried out, and overall noise levels for these runs are shown in Table 4. From this table it can be seen that the drive-by noise levels recorded on the grade 2/4 surface are around 1dBA less than the drive-by noise levels on the grade 3 surface.

Table 4: Overall Drive-by Noise Levels at Site 4

Run No	Drive-by Noise Levels (dBA)	
	1994 Grade 3	1996 Grade 2/4
1	72.9	72.1
2	73.0	72.1

The ⅓ octave band analysis in Figure 6 shows that for the grade 3 surface, the higher drive-by noise level compared to those on the grade 2/4 surface occurs between 40 Hz and 1 kHz (3 to 4 dBA). From the 1 kHz point there is very little difference between the two surfaces.

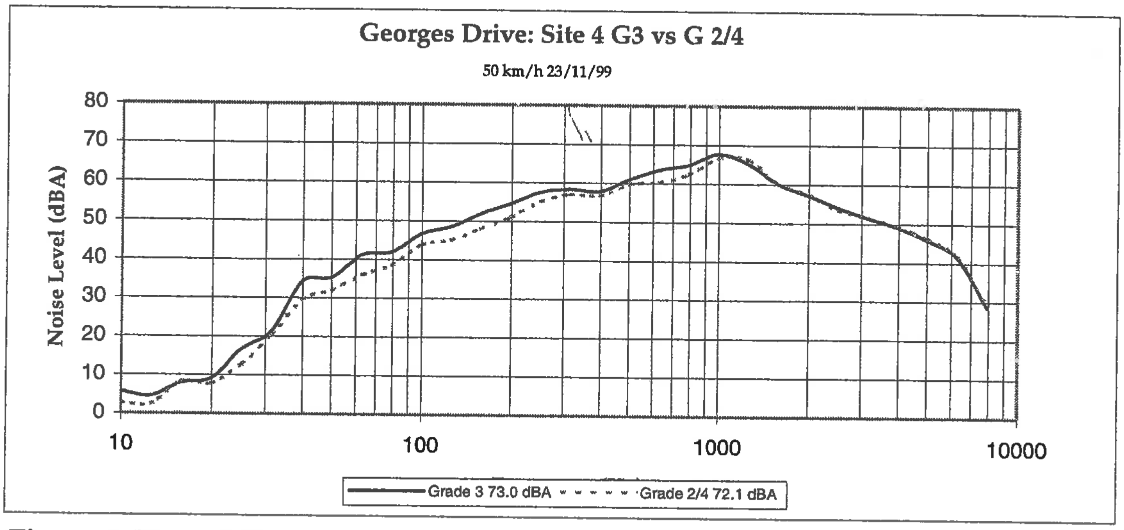


Figure 6: Typical ⅓octave band analyses of drive-by noise on grade 3 and grade 2/4 surfaces at Site 4, Georges Drive, Napier.

It was noted that at this site significant noise was generated by empty truck and trailer units travelling over the uneven surface of this section of road.

6 Comparison of Surfaces

6.1 Chipseal Surfaces

At Site 1, Karamu Road, drive-by vehicle noise levels recorded at the newer grade 2/4 two-coat seal are around 1.5 dBA higher than those for the older grade 2/5 surface. As shown in Figure 3, this difference is most obvious in the lower frequencies, between 150 Hz and 1 kHz. This may be due to a number of reasons, but mainly due to the difference in the macrotextures of the two surfaces. Sand circle measurements show that the older grade 2/5 surface has a finer macrotexture due to the presence of the grade 5 void filling chip, compared to the coarser grade 4 void filling material of the newer surface. This finer macrotexture is also due to the wear effect of 3 years of trafficking, compared with only several months' trafficking of the grade 2/4 surface.

At Site 4, Georges Drive Napier, the drive-by vehicle noise levels recorded for the grade 3 single coat seal are around 1 dBA higher than for the grade 2/4 two-coat surface. As shown in Figure 6, this difference is most obvious in the lower frequencies, between 40 Hz and 1 kHz. This may be due to a number of reasons, but mainly due to the difference in the macrotextures of the two surfaces. Sand circle measurements show that although the grade 2 chip is larger than the grade 3 chip, the grade 2/4 surface has a finer macrotexture due to the presence of the grade 4 void filling chip, while the grade 3 surface has larger voids between the chips.

The racked-in grade 3/5 seal at site 3, Karamu Road produced the highest recorded drive-by levels of all the road surfaces assessed during this study, even though the sand circle measurements show that it has a relatively fine macrotexture. Figure 7 shows the ⅓ octave band analysis of drive-by noise on the chipseal surfaces from the various sites. From this it can be seen that the noise recorded at site 3 is greater than that of the other sites in the higher frequency range, particularly from 1 kHz.

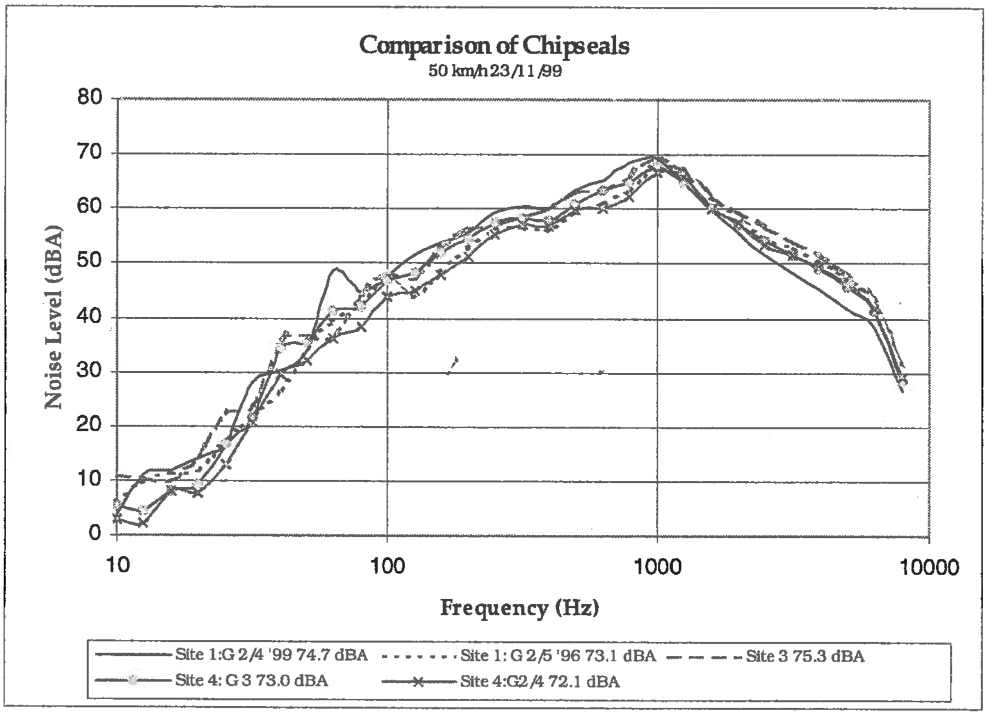


Figure 7: ⅓octave band analyses of dive-by noise on chipseal surfaces at sites 1, 3, and 4.

6.2 Asphaltic Concrete Surface

Figures 8 to 10 show the ⅓octave band analyses of vehicle drive-by noise on the various chipseal sites compared with vehicle drive-by noise on the asphaltic concrete surface of site 2. These figures show that the drive-by noise levels recorded at each of the chipseal sites are around 4 to 7 dBA higher than the levels recorded for the asphaltic concrete surface of site 2, and that these higher levels occur most significantly between 50 Hz and 1.5 kHz. For the 1 kHz frequency, the levels for the chipseal surfaces are around 8 to 10 dBA higher than the levels for the asphaltic material.

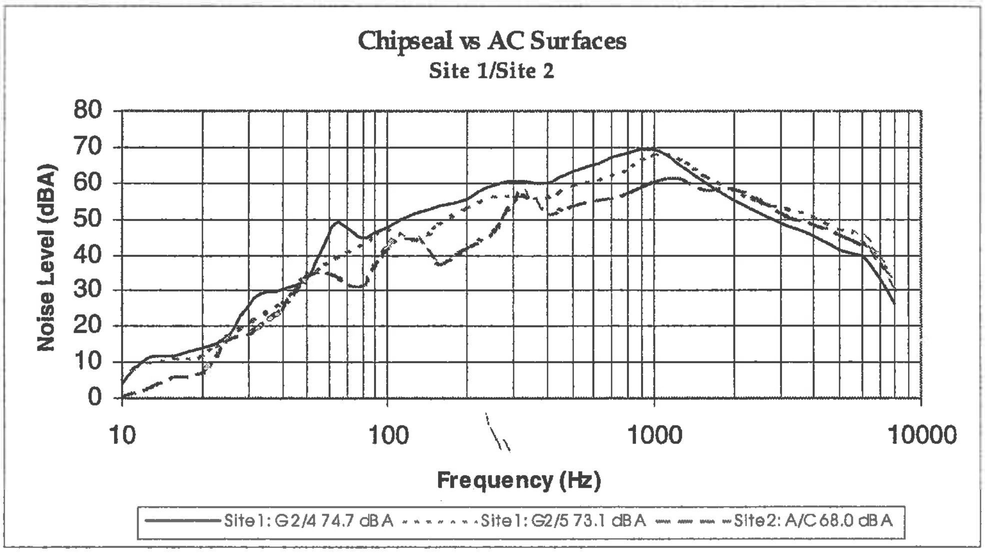


Figure 8: ⅓octave band analyses of drive-by noise on chipseal surfaces at site 1 compared with drive-by noise on the asphaltic surface at site 2

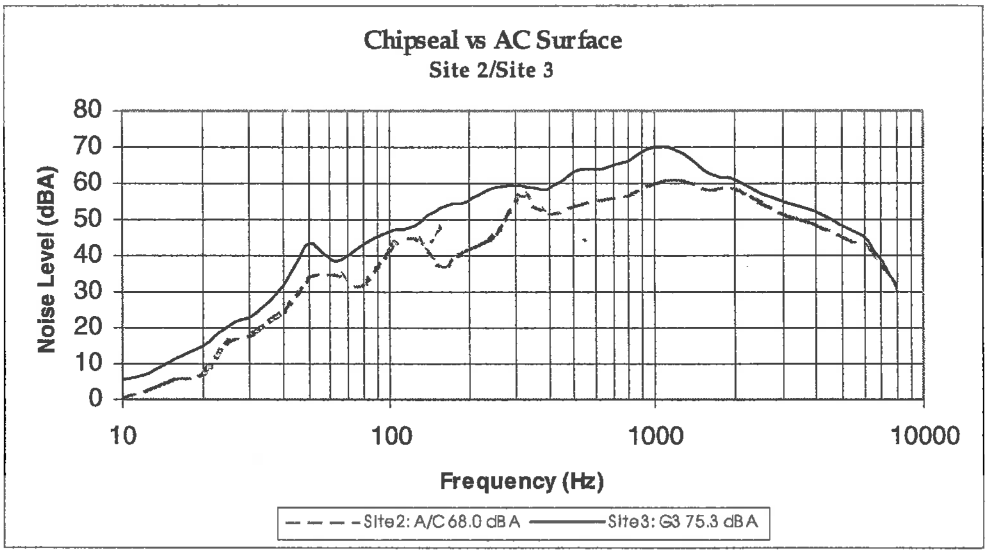


Figure 9: ⅓octave band analyses of drive-by noise on chipseal surface at site 3 compared with drive-by noise on the asphaltic surface at site 2

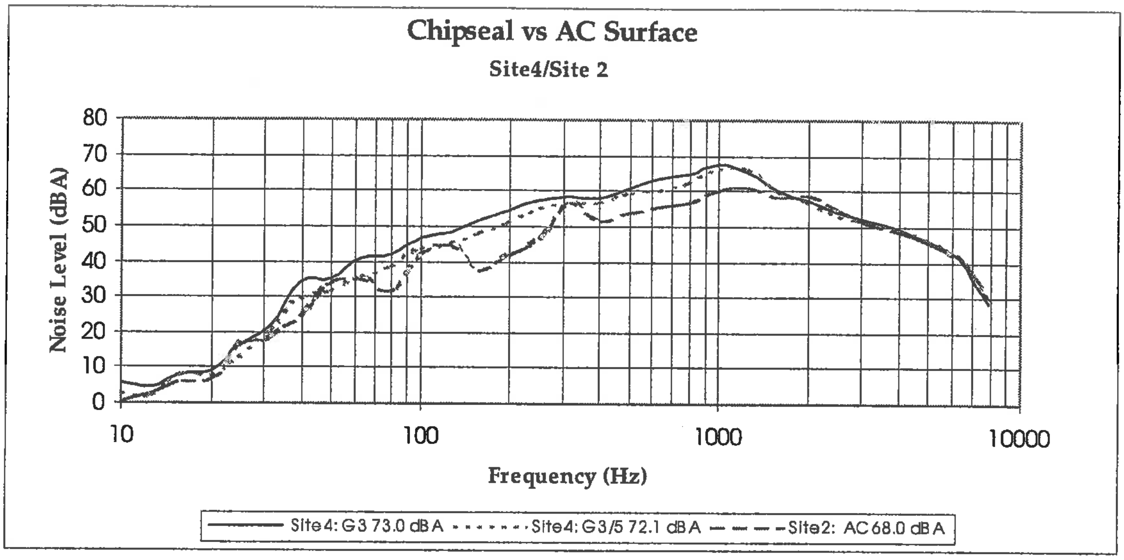


Figure 10: ⅓octave band analyses of drive-by noise on chipseal surfaces at site 4 compared with drive-by noise on the asphaltic surface at site 2

6.3 Discussion of Noise Levels Expected Compared to Measured and Significance of Noise Differences Between Surfaces

It had been expected prior to undertaking this work that the difference in noise levels for the different chipseal surfaces would be of the order of about 2dBA at most. There were a number of reasons for believing this. Firstly the Transit New Zealand Guidelines show in Table E3 the noise levels of different surfaces as follows:

Surface	Noise Correction
Chipseal	+3dBA
Asphaltic Concrete	0
Friction Course	-3dBA

These values are usually applied to open road speed limits of 100 kmph. At lower speeds the corrections for surface types are less certain. Accepted wisdom is that drive-train noise dominates at lower speeds and tyre/road noise at higher speeds, and that for cars, the transition occurs between 40-70 kmph.

It may be however, that this transition occurs at much lower speeds for new cars.

The CRTN model provides corrections for road surface types but they are not applied at speeds less than 70 kmph.

A New Zealand correlation of the CRTN Model was undertaken and a surface correction derived of 5.57 x C (0.71 - log S/V) where C = 1 for chipseal, S = sand circle and V = vehicle speed. Sand circles in this work ranged from 145 to 185mm. Using this formula a difference of about only 0.5dBA should exist between the chipseal surfaces at 50 kmph.

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A further equation is provided in Transit NZ Research Report PR3-0051 where interior car noise was found to increase as 1.69 TD. TD is the mean texture depth as determined by the sand circle test as TD = $57{,}300/D^2$.where D is the sand circle diameter.

The Nordic traffic noise model shows the following noise level corrections relative to asphaltic concrete for several road surfaces, for speeds of up to 60 kmph.

Surface	**Correction (After 1 year)**	**Correction (Newly Laid)**
(Coarse) chipseal 16-20mm	+1	+2
(Medium) chipseal 10-12mm	0	0
(Fine) chipseal 6-9mm	0	-1

With the expectation that the differences in total noise between surfaces would be low it was considered that complaints, should they arise, must be due to differences in tonal content. Therefore the spectral content was also measured.

The table below shows the noise level differences for each site.

Site	**Surface**	**Noise Level**	**Ref Asphalt**[*1]	**Ref Lowest C/S**[*2]
1	2/4	74.7	6.7	2.6
1	2/5	73.1	5.1	1.0
2	Asphalt	68.0	0	-4.1
3	3/5 Racked In	75.3	7.3	3.2
4	3	73.0	5.0	0.9
4	2/4	72.1	4.1	0.0

[*1] Difference in noise level relative to that for asphaltic concrete
[*2] Difference in noise level relative to lowest chipseal noise level

The table shows that unexpectedly there is a marked difference in noise level from these road surfaces even at the low speed of 50 kmph.

Compared to the asphalt surface, noise level increases for chipseal surfaces range from 4.1 to 7.3 dBA. Comparing the chipseals surfaces with the grade 2/4 at site 4, other chipseal surfaces show increases in noise ranging from 0.9 to 3.2 dBA.

A noise increase of 5-8 dBA is substantial. Most people would find an increase of this extent very noticeable but still perceive it as less than a doubling of noise. A 1-3 dBA increase in noise is the level of change in noise which most people would just perceive as a change in noise. This change however could be more noticeable if there was also a change in tonal content.

The following five figures compare the spectra obtained from the car drive-bys over each surface with that for the quietest chipseal surface.

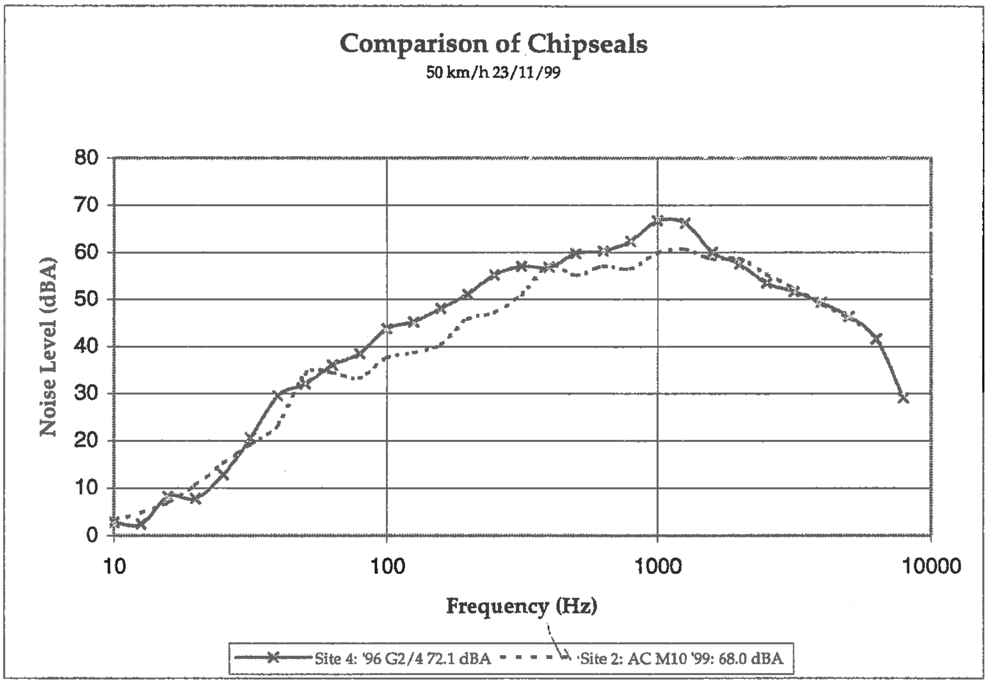

Figure 11: Comparison of ⅓ octave band analyses of drive-by noise: 1996 Grade 2/4(site 4) and 1999 mix 10 asphaltic concrete (site 2)

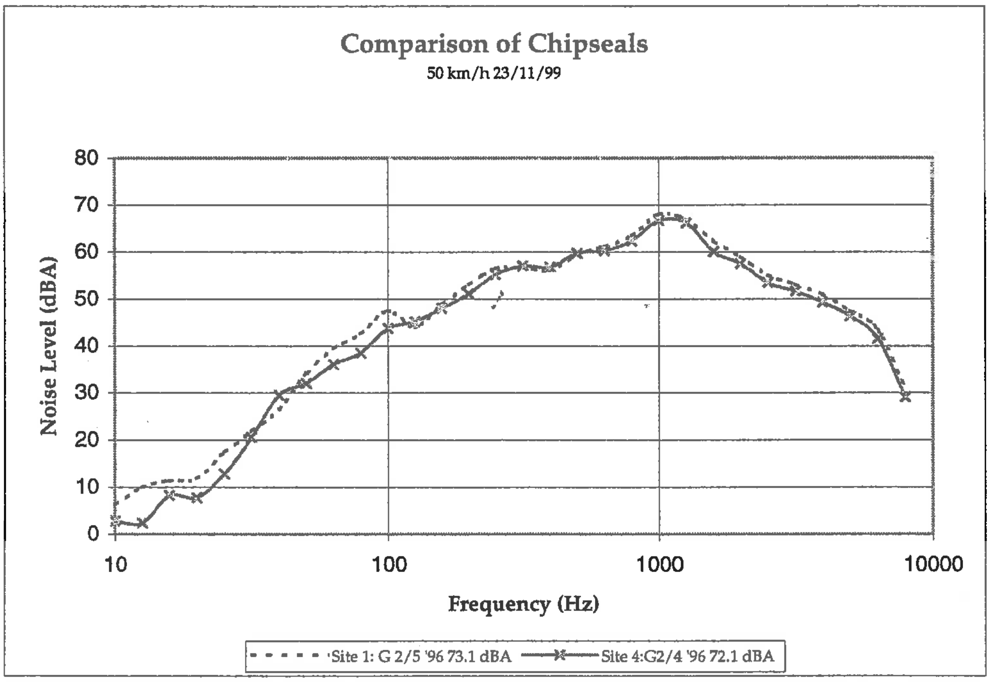

Figure 12: Comparison of ⅓octave band analyses of drive-by noise: 1996 Grade 2/5(site 1) and 1996 grade 2/4 (site 4)

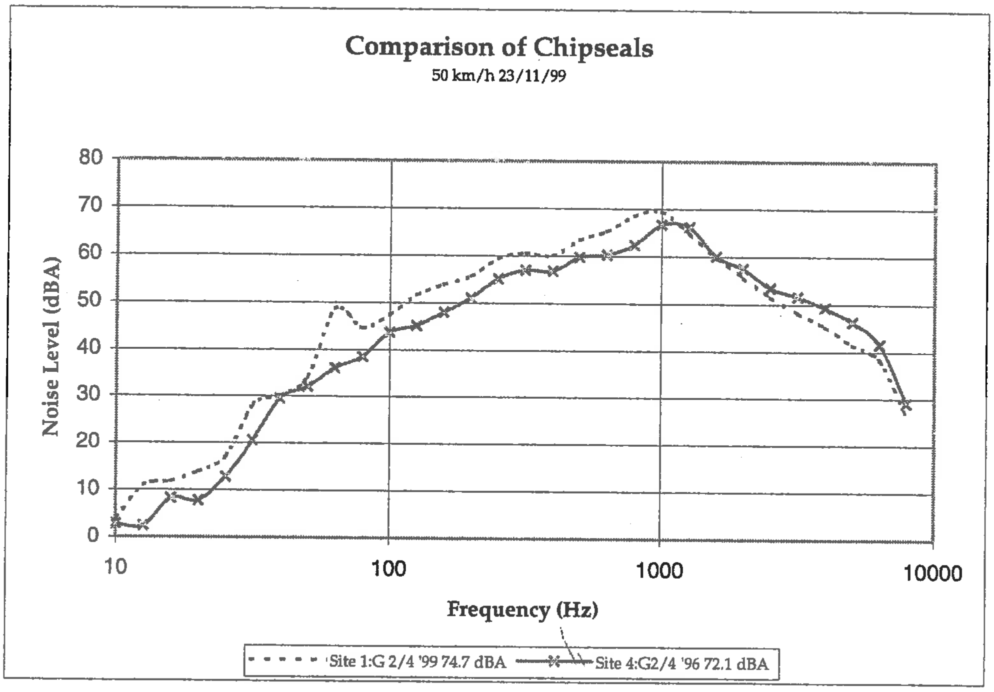

Figure 13: Comparison of ⅓octave band analyses of drive-by noise: 1999 Grade 2/4(site 1) and 1996 grade 2/4 (site 4).

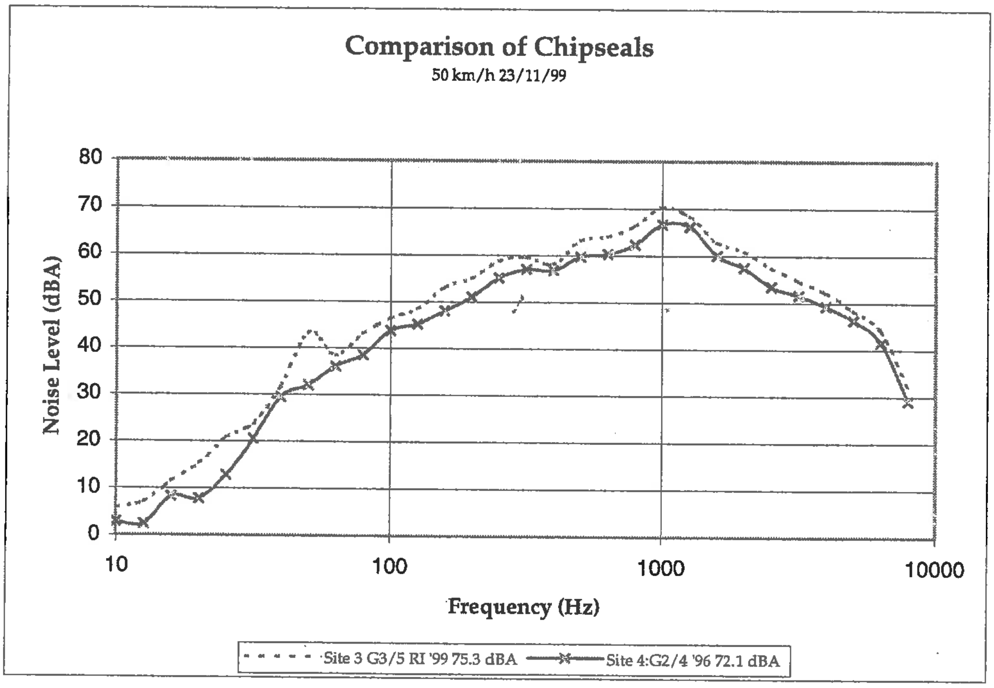

Figure 14: Comparison of ⅓octave band analyses of drive-by noise: 1999 Grade 3/5 racked-in seal (site 3) and 1996 grade 2/4 (site 4).

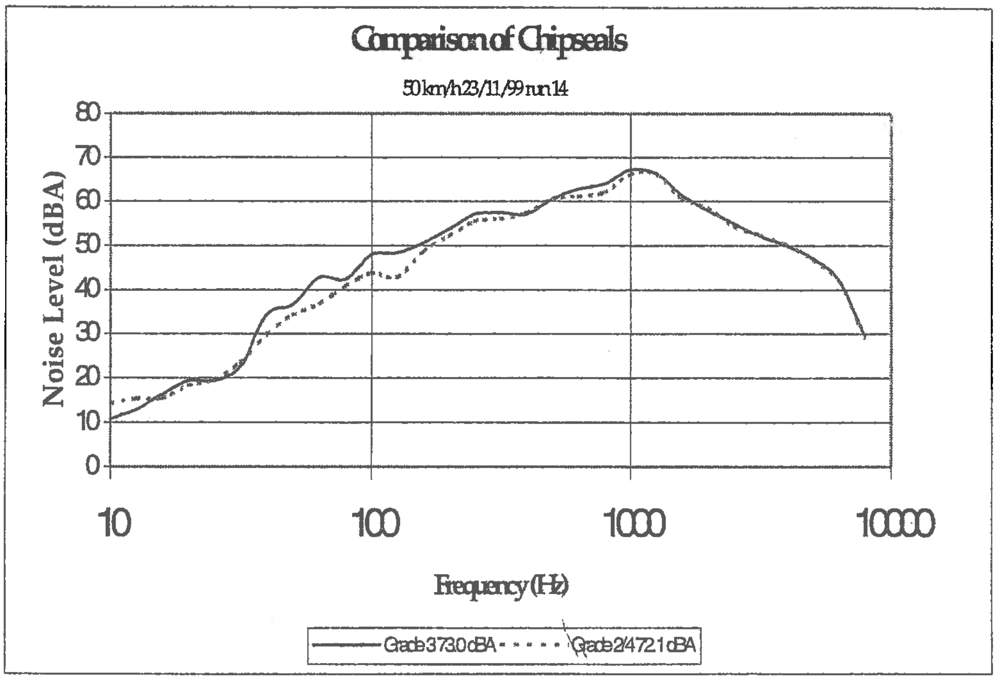

Figure 15: Comparison of ⅓octave band analyses of drive-by noise at Site 4: 1994 Grade 3 reseal and 1996 grade 2/4.

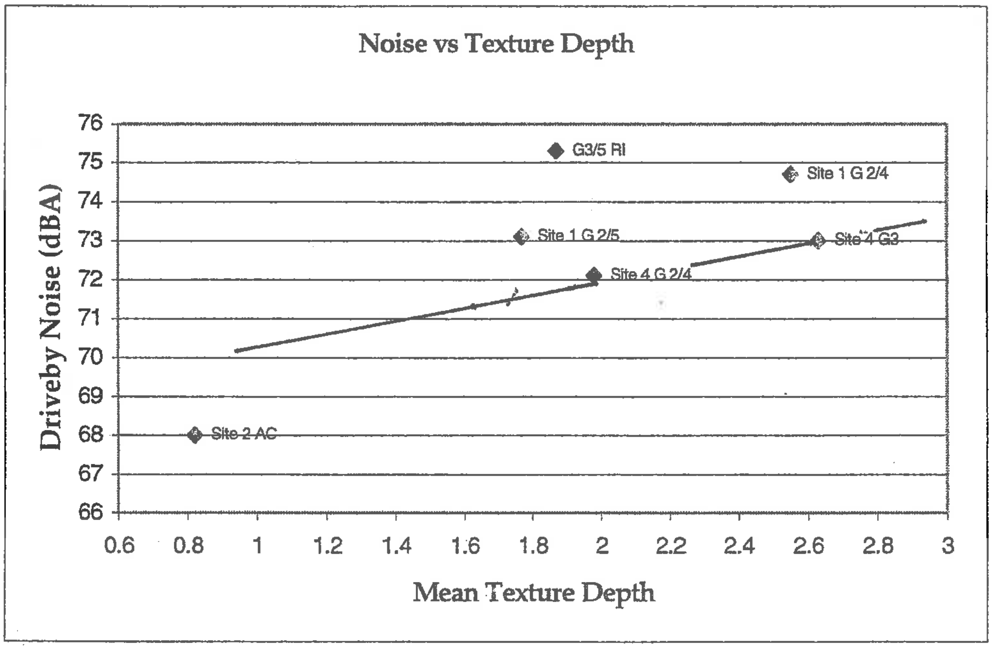

Figure 16: Noise Level vs. Mean Texture Depth

Figure 11 compares the quietest chipseal with the asphalt. Firstly there is a change in noise of 4dBA. In addition the spectrum for the chipseal between 100 HZ and 2kHZ is larger by as much as about 7dBA over most of this frequency range. The spectrum has moved noticeably towards the lower end and the sound on the chipseal will appear quite noticeably rough or more of a "roar" from the passing tyre.

Figure 12 shows that the grade 2/5 at site 1 and the 2/4 at site 4 have almost identical spectra. It is likely that no difference in noise between the surfaces would be detected.

Figure 13 compares the new grade 2/4 at site 1 with the older grade 2/4 at site 4. In the important area of 100 HZ to 4000 HZ the spectrum are similar but with a noticeable displacement to the lower frequency end. The new grade 2/4 is more noisy overall by nearly 3dBA, a moderate change, but in the 100-1000HZ range the increase is about 4-5dBA greater. We would expect the differences in the surfaces to be quite noticeable, with the grade 3 having slightly more noise and a bit more rough sound. The spectrum is consistent with the newer surface being not as worked in as the older surface.

Figure 14 compares the grade 3/5 with the grade 2/4 at site 4. Overall the spectra are very similar, but with the grade 3/5 spectra being displaced vertically by almost 3dBA. The grade 3/5 would appear a little more noisy but of the same tones as the grade 2/4. It could be that the new 2/4 at site 1 is more noticeably different from the old 2/4 than the 3/5 is from the old 2/4 because of the accompanying shift in the spectra, but community response testing would be needed to show this.

Figure 15 shows the spectra of the grade 3 and grade 2/4 at site 4. After 1000 kHZ the spectra are identical. Between 100 and 1000 HZ the grade 3 is slightly more noisy, about 1-2 dBA. It is likely that those adjacent would detect a difference only by listening closely as the vehicles cross from one surface to the other. The grade 3 may just give a little noise "roar".

Figure 16 helps to illustrate the unexpected nature of the results. This figure shows noise level versus mean texture depth. Mean texture is often taken as a sole indicator of noise, although it is known specific components of the texture depth distribution also have a strong influence in determining noise.

The growth in noise with increasing texture depth (TD) is given by several similar equations.

PR3-0051 shows noise increasing at 1.69 x TD. The NZ CRTN correlation equates to 0.55 x TD at 50 kmph.

Drawing a line with a slope of 1.69 through the grade 3 (73 dBA 2.6mm texture depth) shows that the racked in grade 3/5 racked in especially and the new grade 2/4 and 2/5 are lying above this line. This shows that they are giving significantly more noise (1-3.5 dBA) than anticipated. This anomalous result might be explained if more in depth information on the texture such as that available from the laser profilometer was available but laser profilometer measurements were not done in this instance.

6.4 Conclusions

These noise measurements have shown a higher than expected difference in noise between this set of road surfaces. The magnitude of this difference could result in a detectable and sometimes significant perceived change in noise levels for those living adjacent to these roads. Changes in tonal content of the noise also occur. This change in tonality might heighten the ability of adjacent residents to detect changes in noise level.

Reviewed by

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APPENDIX A

ROAD SURFACE DATA

Site 1. Karamu Road (RP 661/8.41)

Seal 1: (North of seal joint)			
Grade 2/5 two coat seal	Sealed: 23/01/96	ALD of Grade 2 chip = 11.54mm	
Sand Circle Measurements:	Left Wheel Track	185mm	
	Right Wheel Track	175mm	
Seal 2: (South of seal joint)			
Grade 2/4 two coat seal	Sealed: 22/02/99	ALD of Grade 2 chip = 11.46mm	
Sand Circle Measurements:	Left Wheel Track	140mm	
	Right Wheel Track	160mm	

Site 2. Willowpark Road

Asphaltic Concrete Type: Mix 10 Table 2 Depth: 25mm overlay Laid: 26/06/99
As an indication of texture depth, sand circle diameter was 265mm.

Site 3. Karamu Road (RP 661/9.4)

Seal is:			
Grade 3/5 racked-in seal	Sealed: 16/03/99	ALD of Grade 3 chip = 9.92mm	
Sand Circle Measurements:	Left Wheel Track	170mm	
	Right Wheel Track	180mm	

Site 4. Georges Drive (RP 650/1.98)

Seal 1: (North of seal joint)			
Grade 2/4 two coat seal	Sealed: 20/03/96	ALD of Grade 2 chip = 10.53mm	
Sand Circle Measurements:	Left Wheel Track	185mm	
	Right Wheel Track	155mm	
Seal 2: (South of seal joint)			
Grade 3 reseal	Sealed: 22/02/94	ALD of Grade 3 chip = 8.44mm	
Sand Circle Measurements:	Left Wheel Track	150mm	
	Right Wheel Track	145mm	