Road Surface Effects on Traffic Noise: Stage 3 – Selected Bituminous Mixes

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An important note for the reader

Land Transport New Zealand is a crown entity established under the Land Transport New Zealand Transport Management Act 2003. The objective of Land Transport New Zealand is to allocate resources and to undertake its functions in a way that contributes to an integrated, safe, responsive and sustainable land transport system. Each year, Land Transport New Zealand invests a portion of its funds on research that contributes to this objective.

This report is the final stage of a project commissioned by Transfund New Zealand before 2004, and is published by Land Transport New Zealand.

Abbreviations

AC: Asphaltic concrete

APAA: Australian Asphalt Pavements Association

CRTN: Calculation of Road Traffic Noise (UK Department of Transport 1988)

DGA: Dense graded asphalt

Nordic: Nordic Road Noise Prediction (Nordic Council of Ministers 1996)

OGA: Open graded asphalt

OGPA: Open graded porous asphalt

SMA: Stone mastic asphalt

Contents

Executive summary

Introduction

An earlier study reported the noise effects of a selection of typical New Zealand road surfaces, covering a broad range of types from low-textured bituminous mix surfaces through to large-textured surfaces such as one- and two-coat chipseals. The previous study also examined the noise impact on communities adjacent to roads.

This current report, undertaken in 2004–2005, expands on the earlier study. In particular, it looks in much more detail at the range of low-textured bituminous mix surfaces and the effect that they have on road traffic noise. Examples of these bituminous mix surfaces that were included in this study include:

- asphaltic concrete (AC), also known as dense graded asphalt (DGA);
- stone mastic asphalt (SMA);
- macadam;
- open graded porous asphalt (OGPA), also known as open graded asphalt(OGA); and
- slurry seals.

Both reports sought to identify the noise effect of different surfaces relative to an asphaltic concrete surface made with graded chip sizes of a maximum size of 10 mm (often referred to as AC-10). This current study also sought, if possible, to identify if any regional variationof noise effects of surfaces of the same type could be found within New Zealand.

Road surface types in New Zealand

Road surface types used in New Zealand fall into two categories, chipseal or bituminous mix.

Chipseal surfaces (also known in other countries as spray-seals or surface dressings) consist of a layer of bitumen sprayed onto the road surface, into which a layer of aggregate of a specific size is embedded. The bitumen layer is only about 30 to 50 % of the aggregate chips' diameter so that the travelled surface is the aggregate only. As in other countries, two-coat seals, where a smaller chip is fitted into the matrix of a larger chip, are also used in New Zealand.

Bituminous mix surfaces are usually used in urban areas on roads with greater traffic volumes, on motorways and on higher stress areas where the greater mechanical strength of this surface type is required.

Bituminous mixes differ markedly from chipseal. They contain a graduation of aggregate sizes from fine to coarse. The aggregate chips are first mixed with bitumen before being laid on the road surface. The bitumen-coated chips are compacted tightly together to form one or more layers, typically 20 to 40 mm thick, but 90 mm is sometimes used. The ratio of finer to coarser chip is controlled to generate surface types with differing surface textures and differing porosities.

Within the group of bituminous mixes, different surface types arise according to the relative combinations of stone chip sizes and bitumen content. Surface types are named according to both their overall design and the maximum chip size they contain. For example, AC-10 is asphaltic concrete containing a maximum sized chip of 10 mm.

Noise measurement methodology

The methodology of measuring the effect of the road surface on traffic noise used in this study followed that of the previous study, being the statistical pass-by method with the vehicle in 'cruise-by' mode, but with some variations.

The first study had used a 'test vehicle' on a selection of test road surfaces for the noise measurements. At about five of the measurement sites, 10 to 20 vehicles of each site's general vehicle stream were sampled to ensure that the 'test vehicle' was relevant to the rest of the vehicle fleet. In the current study, the average noise levels for each test road surface were calculated from noise measurements of a random sample from the general traffic stream, with each site's sample consisting of 20 to 22 cars and 10 to 12 heavy trucks.

As in the previous study, measurements for this study were made by capturing one second of noise as the subject vehicle was directly adjacent to the sound meter. The noise was sampled at 16,000 Hz with 0.5 seconds either side of the peak selected for analysis of spectral content and total noise level. As in the previous study, the spectral content was used to:

- help confirm that the predominant noise was tyre–road noise,
- verify the consistency of measurement, and
- assist in identifying trends with speed and between surface types.

Measurement of a vehicle in 'cruise-by' mode requires that the vehicle is neither accelerating nor decelerating. Taking a sample from the general passing vehicle stream means that driver behaviour cannot be controlled directly so an indirect control is used, which is to select test sites that are flat, straight and as far away as possible from intersections. In these situations, drivers should be travelling in the 'cruise-by' mode. Vehicles that appeared to be behaving erratically, accelerating or decelerating were excluded from the sampling.

Measurements were undertaken on roads with posted speed limits of 50, 60 or 70 km/h. Actual on-site traffic speeds at the time of the noise measurements were determined by using a test vehicle driven within the traffic flow passing the site, and repeating this manoeuvre four to five times. The driving speed of the test vehicle was recorded and used to calculate the average real speed of the traffic flow.

Results

Table XS1 consolidates data from both this study and the previous study. The table shows the effect different bituminous mix road surfaces have on noise levels. Based on the results from both studies, it appears that the values in the table hold true for traffic speeds between 50 and 100 km/h.

Table XS1 Recommended road surface effects relative to AC-10, for use with New Zealand bituminous mix roads (dBA).

Surface		Correction to use for	
Category	**Type**	**Cars**	**Trucks**
AC	10 mm	Ref.	Ref.
	14 mm	0	0
	16 mm[a]	0	0
OGPA	OGPA-14, 20% voids	0	-2.0
	OGPA-14, 30% voids	-2.0	-3.0
	70 mm double-layer, Wispa	-2.0	-4.0
Capeseal[b]	#2/Type 3 (coarse)[a]	+3.0	+1.0
	#3/Type 2 (general)[a]	+2.0	-1.0
	#4/Type 1 (fine)[*2]	0	-1.0
SMA	10	+1.5	-1.5
	11	+1.5	-1.5
	14[*2]	+1.5	-1.5
Slurry seal	Type 3 (coarse)[a]	+1.0	-1.0
Macadam		+3.0	0
Chipseal	Grade 6 (smallest chip)	+3.0	-2.0
	Grade 5	+3.0	-2.0
	Grade 4	+3.0	-2.0
	Grade 3	+4.0	+1.0
	Grade 2 (largest chip)[a]	+6.0	+1.0
Two-coat seals	Grade 4/6	+5.0	+1.0
	Grade 3/5	+6.0	+1.0
	Grade 3/6	+6.0	+1.0
	Grade 2/4	+6.0	+1.0

Notes to Table XS1:

a Results indicative only as data have been taken from a very small sample.

b Capeseal is chipseal followed by a layer of slurry seal.

The values in the table can be used to improve the accuracy of noise prediction when using noise models. However, a more important use is to identify the noise improvement that would occur if an existing road surface was to be replaced by a surface with a lesser noise effect. The noise effect of a road surface is separate for cars and for trucks, so the overall noise effect of the surface will be specific to the particular proportional combinations of cars and trucks that form the vehicle stream on the road under consideration, and must be calculated as such.

Conclusions

1. The road surface type has a significant effect on traffic noise generated. The road surface effect can range up to 8 dBA and the effect differs between cars and trucks.

2. The road surface effect for bituminous-mix road surfaces ranges up to about 5 dBA.

3. No regional variation was noted in the surface effect on traffic noise for surfaces of the same type, being surfaces made to the same Transit New Zealand specification.

4. Previous studies have shown that resealing a road to create a change in traffic noise as small as 1 to 3 dBA can affect the satisfaction of residents adjacent the roads. Given that bituminous mix surfaces are generally used on roads with greater traffic volumes, which are noisier roads, care is needed in selecting the surface type of the reseal, as the local noise environment can be significantly altered.

Abstract

The noise from road traffic affects large numbers of people living in the vicinity of State Highways and arterial roads. An increasingly important aspect of developing traffic noise reduction measures is the definition of 'quiet' road surface types and their application in affected areas. This project, undertaken in 2004–2005, identifies the noise effect that different low macro-texture bituminous mix road surfaces, such as asphaltic concrete, slurry seal, open graded asphalt and stone mastic asphalt, have on road traffic noise at urban driving speeds and at open road speeds.

Significant noise variations, of the order of 2 to 3 dBA, could occur between different bituminous mix road surfaces within the same generic type. While noise reductions as small as 1 to 2 dBA were previously regarded as too small to be significant, it appears that such reductions could actually be of considerable benefit to the community living adjacent to busy urban roads.

Selecting a quieter road surface type when resealing can be a highly effective measure if roading engineers wish to reduce traffic noise.

1. Introduction

This project follows on from the project 'Road traffic noise: determining the influence of New Zealand road surfaces on noise levels and community annoyance' (Dravitzki et al. 2006). This previous study examined the noise effects of a broad range of road surfaces from several low-textured bituminous mix type surfaces, through to large-textured surfaces such as one- and two-coat chipseals.

This current study, undertaken in 2004–2005, expands on the earlier study. In particular, it looks in much more detail at the range of low-textured surfaces made from bituminous mixes and the effect that they have on road traffic noise. These bituminous mix surface types are, for example, open graded porous asphalt (OGPA), stone mastic asphalt (SMA), various grades of asphaltic concrete (AC), macadam and slurry seals.

These two studies sought to identify the noise effect of different surfaces relative to an asphaltic concrete surface made with graded chip sizes of a maximum size of 10 mm (often referred to as AC-10). This current study also sought, if possible, to identify if any regional variation of noise effects of surfaces of the same type could be found within New Zealand.

2. Background

The surface types measured in this project were all of the bituminous mix type. Road surfaces from bituminous mixes are made by firstly mixing different sizes of stone chips together with bitumen then laying this mix onto the road surface. This is in contrast with the other main type of road surface used in New Zealand, that of chipseal, which is made by applying a bitumen layer to the road surface then embedding aggregate chips in this layer while the bitumen is still hot.

Road surface types are named according to both their overall design and the maximum chip size they contain. For example, AC-10 is asphaltic concrete containing chips with a maximum size of 10 mm. The bituminous mixes included in this project are:

- AC, also known as dense graded asphalt (DGA);
- stone mastic asphalt;
- macadam;
- OGPA ,also known as open graded asphalt (OGA); and
- slurry seals.

The various bituminous mixes differ according to their relative combinations of aggregate chip sizes and bitumen content, as shown in Figures 2.1 to 2.3.

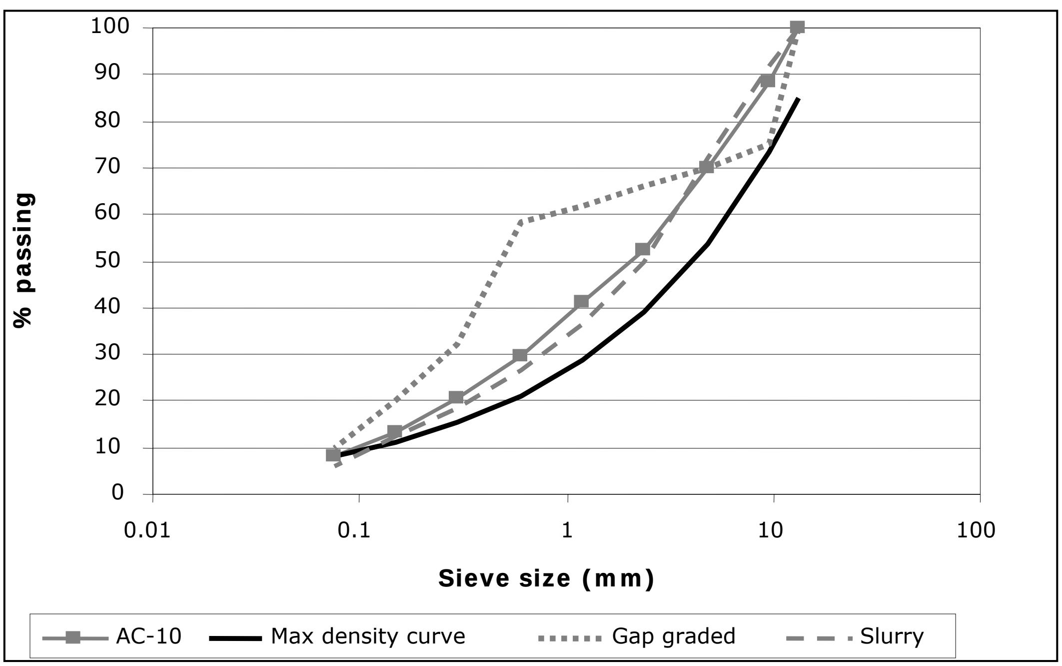

Figure 2.1 Graduation of aggregate chip sizes in dense graded mixes.

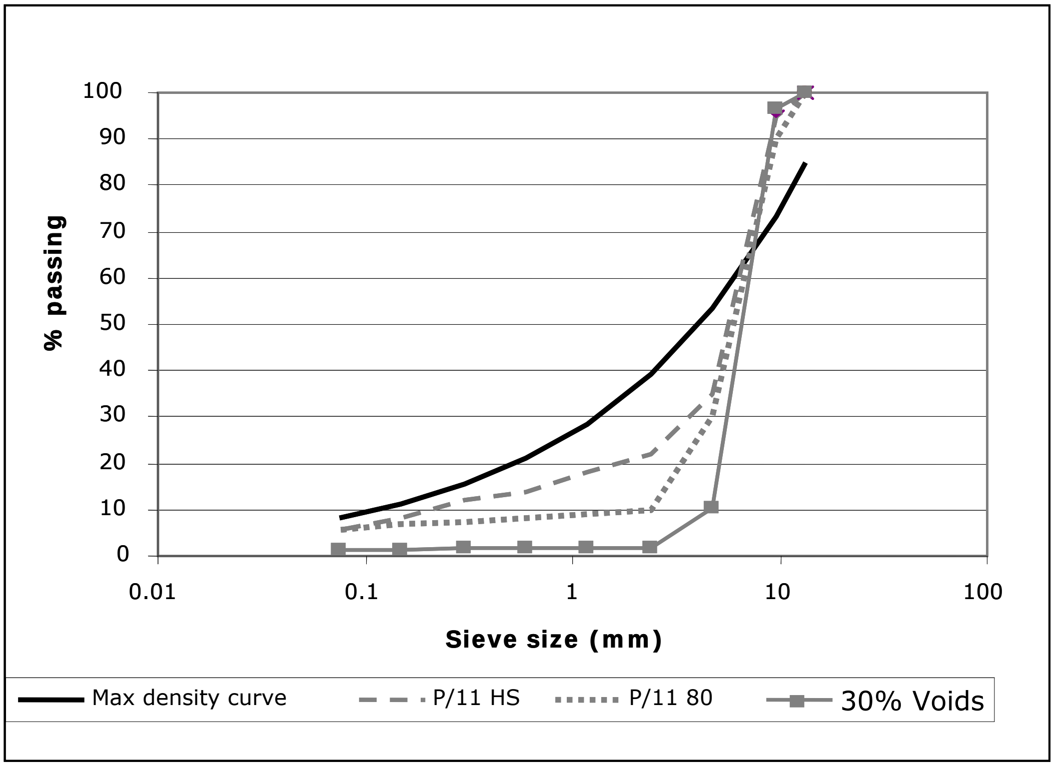

Figure 2.2 Graduation of aggregate chip sizes in porous asphalt mixes.

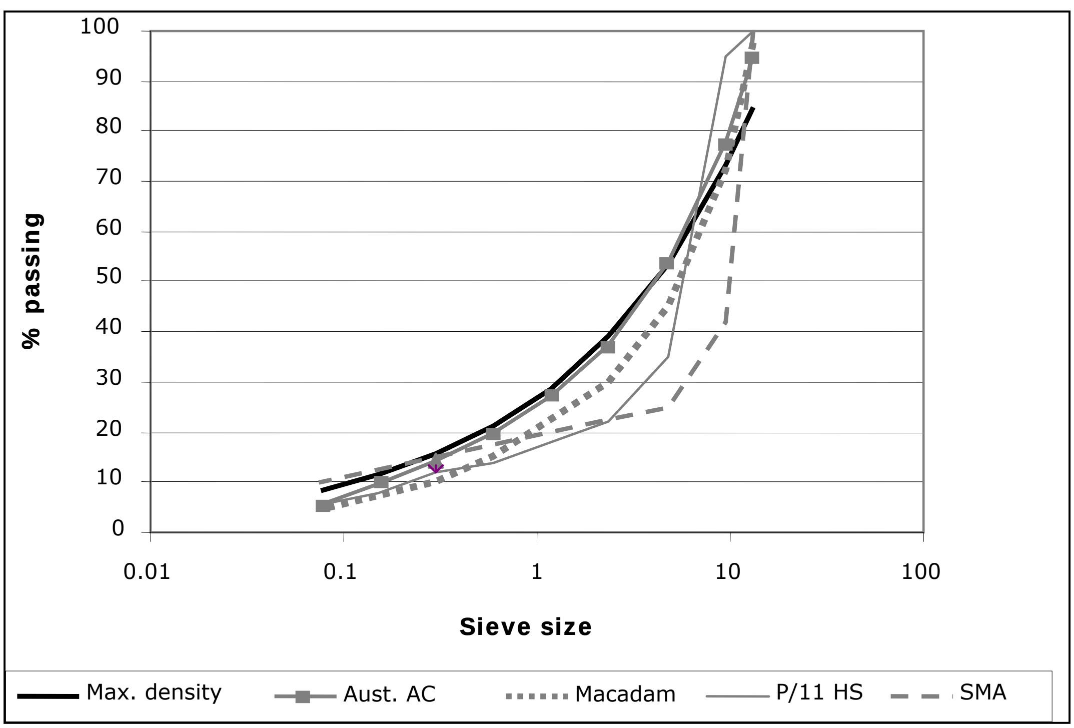

Figure 2.3 Graduation of aggregate chip sizes in specialised bituminous mixes.

These figures show a series of aggregate chip size distributions for the surface types that were measured for noise effects within this study.

The curve denoting 'maximum density' on each figure (solid black line) is the theoretical density of a material that could be made from a continuously graded material. AC-10 and slurry seal lie to the left of this and so are dense graded mixes. These dense graded mixes contain a higher proportion of fines and consequently have a low-textured surface.

Figure 2.2 shows the porous asphalt mixes. These lie to the right of the theoretical 'maximum density curve'. These comprise mainly large aggregate chip sizes with very small proportions of fines, thereby making these surfaces very porous. Compared to AC-10, the surface created with these porous asphalt mixes has a similar 'level' profile at its uppermost trafficked surface, as the stones are aligned by the laying machine, but this top surface is pitted by the porous texture of the material.

Figure 2.3 shows that the SMA mixes are similar to the porous asphalt mixes, containing a high proportion of larger size aggregate chips and therefore lying to the right of the theoretical 'maximum density curve'. But compared to the porous asphalt mixes, the SMA mixes contain more fines and therefore are not porous. Compared to AC-10, the uppermost trafficked surface of a SMA road surface will have a pronounced texture created by the larger stones in its mix. Figure 2.3 also shows macadam (made to an Opus International Consultants in-house specification). Macadam has more larger-sized aggregate chips than AC-10 and fewer fines, so the macadam road surface, like an SMA road surface, has a more pronounced texture than AC-10 and is not porous.

The specific surfaces tested in this work were:

- AC-10, AC-14 and AC-16;
- SMA-10, SMA-11 and SMA-14;
- macadam-14;
- slurry-3; and
- OGPA-14 and OGPA-25.

In addition, a parallel project being undertaken for Transit New Zealand (Dravitzki & Kvatch 2004), using the same methodology as this project, measures the noise effect of several other surface types in a motorway setting. These surfaces were:

- high voids OGPA (30% voids),
- high voids double layer OGPA,
- macadam,
- ultra-thin asphalt, and
- conventional OGPA-14.

For completeness, these results have also been included in this report with their origins appropriately annotated.

3. Methodology

3.1 Sampling

The methodology used in this study followed that used in the previous study (Dravitzky et al. 2006), being the statistical pass-by method with the vehicle in 'cruise-by' mode. The first study had used test vehicles for most measurements. At about five of the test sites, 10–20 vehicles of the actual vehicle stream at that site were sampled to ensure that the 'test vehicle' was relevant to the rest of the vehicle fleet. An analysis within that study found that any five of the fleet vehicles (separated first into light or heavy vehicle categories) gave a mean value within 1 dBA of the mean of any other group of five vehicles. This illustrated that a viable method of determining road surface noise effects was to take a sample of the passing vehicle fleet, appropriately divided into light or heavy vehicle categories, and to establish the mean value of the noise effect of the surface for that fleet sample. This is the method used in the parallel Transit New Zealand programme and was used for this current project in determining the noise effect of the bituminous mix road surfacings.

In this study, average noise levels for each surface were calculated using noise measurements of 20–22 cars and 10–12 heavy trucks. Previous research (Dravitzki et al. 2006) showed that this was a large enough sample to produce a characteristic noise level for each surface type.

Measuring a vehicle in 'cruise-by' mode requires that the vehicle is neither accelerating nor decelerating. Taking a sample of the passing fleet means that driver behaviour cannot be controlled directly so an indirect control is used, which is to select a test site which is flat and straight and as far away as possible from intersections. In these situations, drivers should be travelling in the 'cruise-by' mode.

Bituminous mix surfaces are usually used in urban areas on higher traffic volume roads, on motorways and on higher stress areas where their greater mechanical strength is required. Several of the surfaces, such as macadam and SMA, are mainly used only in high stress areas (such as on corners, roundabouts and stopping areas). As a consequence, few sites met the criteria of the methodology for this study (i.e. straight and flat with the trafficking vehicles moving at a steady speed).

At all sites, the noise meter was installed 2.5 m from the traffic lane's edgeline and a microphone was positioned 1.2 m above the ground level. While it may be preferable to place a noise meter offset five meters from the traffic, in a number of situations, measurements at this distance can be impeded by roadside features (e.g. signage, grass verges, traffic islands, embankments and ditches). Trials have shown that the distance between the noise meter (microphone position) and the edge of traffic lane could be adapted to 2.5 m at all monitoring sites. However, at this separation, the real distance between the vehicle track and the noise meter can vary significantly depending on the vehicle type, road width and driving conditions. Observations show that this 'real distance' can vary approximately from 2.5 m to 5 m for light cars, and from 2.5 m to 4 m for heavy trucks. In the series of measurements made in this study, only vehicles travelling in approximately the centre of the traffic lane were recorded. Vehicles travelling very close to or too far from this position in the traffic lane were not included.

Measurements were made capturing one second of noise as the vehicle was directly adjacent to the meter. This 'capture' was then analysed for spectral content and total noise level, using 0.5 seconds of data either side of the instant of maximum noise level.

3.2 Vehicle speeds

Measurements for this study were undertaken on roads with posted speed limits of 50, 60 or 70 km/h. However, as 'real' mean driving speeds can differ from the posted speed limit, actual traffic speeds were determined at the time of measuring via a reference vehicle driven within the traffic flow passing the site, repeated four to five times. The driving speed was recorded and the average real speed of traffic flow was calculated. The more obvious method of measuring on-site speed using a radar gun was avoided as it was likely that drivers would change their speed if they saw the speed measurement being made.

3.3 Adjusting for speeds

The road surfaces tested in this study were in different speed zones and the mean speed in some of the zones appeared to be greater than the posted speed. Noise levels increase with vehicle speed so to compare surfaces, they need to be adjusted to a common speed, chosen in this study as 50 km/h.

Guidance was sought from the existing Nordic Road Noise Prediction (Nordic) model (Nordic Council of Ministers 1996) and the Calculation of Road Traffic Noise (CRTN) model (UK Department of Transport 1988) on how this adjustment should be made. The Nordic model, appeared to be more useful than the CRTN model as it had separate effects for cars and trucks.

The Nordic model shows the relationship of vehicle noise and speed as being 25log(v/50) for light vehicles and 30log(v/50) for heavy vehicles. These values are altered from an earlier version of the model which had the expected relationship of vehicle noise and speed for heavy vehicles as 20log(v/50).

Dravitzki et al. 2006) measured the noise effect of test vehicles at different speeds on about seven different road surface types. For the light vehicles, the difference between noise levels at 50 km/h and those at 100 km/h was found to vary between 8 to 11 dBA depending on the road surface. This fits with a speed dependency close to 30log(v/50). For the heavy vehicles, noise increased by 4 to 5 dBA as speed increased from 50 to 90 km/h, indicating a relationship of noise to speed of approximately 20log(v/50).

These relationships for New Zealand vehicles are in greater accordance with the older (1983) version of the Nordic model than the 1996 version, although it is the 1996 version that was validated and found to be reliable in New Zealand (Wood et al. 1997). However, in that validation, most of the surfaces considered were chipseal and the vehicle fleet used was a composite of light and heavy vehicles. Thus the combined effect of the two vehicle types on the noise effect may have masked any individual differences.

3.4 Site description

Locations and details of the road surface at the measurement sites included in this study are shown in Table 3.1.

Table 3.1 Sites used for measuring road noise.

Road surface	Site location		Sealed	Age (years)
AC-10	1	Auckland, 373 Neilson Street	13/01/98	7
	2	Auckland, 131 Abbotts Way	12/03/96	8
	3	Auckland, 102 Great South Road	2003–04	1–2
AC-10	4	Lower Hutt, 359 Waiwhetu Road	07/02/01	3
	5	Lower Hutt, Wainui Road (Lady of the Rosary School)	28/01/01	3
	6	Lower Hutt, Cambridge Terrace Waterloo Bridge (northbound)	15/05/01	3
	7	Lower Hutt, Cambridge Terrace Waterloo Bridge (southbound)	15/05/01	3
AC-14	9	Auckland, 50 Mangere Road	6/02/00	4
	10	Auckland, 117/119 Abbotts Way (eastbound)	12/09/02	3
	11	Auckland, 150 Church Street (Spring–Victoria Street section)	12/02/03	2
AC-16	12	Dunedin, South Road (Eastborne Street intersection)	2003	2
SMA-11	13	Auckland, Campbell Road (Massey Avenue intersection)	20/03/04	1
	14	Auckland, Smart Road	24/10/02	2.5
	15	Auckland, 294 Ellerslie Panmure Highway	4/02/03	3
	16	Auckland, 350 Ellerslie Panmure Highway	4/02/03	3
SMA-10	17	Hamilton, Te Rapa Road	28/02/04	1
	18	Hamilton, 425 Ulster Street	20/12/02	2
SMA-14	19	Hamilton, Wairere Drive (opposite Quantum Lodge)	25/12/02	2
Macadam	20	Dunedin, Great King Street (Duke–Howe St section)	2003	2
Slurry 3	21	Dunedin, Great King Stret (Union–David)	2003	2
	22	Dunedin, Anzac Avenue	19/02/04	1
	23	Dunedin 333 Kaikorai Street	2004	1
OGPA-14	24	Dunedin, 249 Taieri Road	2000	4
	25	Tauranga, Turret Road (rest area)	04/2003	2
	26	Tauranga, Fifteenth Avenue (opposite No 182/184)	03/2003	2
OGPA-25	27	Tauranga, Takitimu Drive (northbound)	12/2000	4

4. Results

4.1 Measured results

Table 4.1 Noise levels from trial sites as recorded.

Road surface	Site location	Noise level (dBA)		Assessed km/h
		Cars	Trucks	
AC-10[a]	Lower Hutt, 359 Waiwhetu Road	74.5 73.4	83.3, 84.8	55
	Lower Hutt, Wainui Road	73.8, 72.6	83.9, 84.6	50
	Lower Hutt, Cambridge Terrace Waterloo Bridge (northbound)	73.8, 72.8	84.8, 84.7	50
	Lower Hutt, Cambridge Terrace Waterloo Bridge (southbound)	74.2, 73.1	84.5, 84.5	50
	Lower Hutt, 408 Cambridge Terrace	74.2, 73.6	83.2, 84.6	55
AC-10	Auckland, 373 Neilson Street	75.1	85.1	55
	Auckland, 131 Abbots Way	75.0	84.6	60
	Auckland, 102 Great South Road	75.1	83.5	55
AC-14	Auckland, 50 Mangere Road	74.4	83.8	55
	Auckland, 117/119 Abbotts Way (eastbound)	75.3	86.0	60
	Auckland, 150 Church Street (Spring–Victoria St)	72.7	85.0	50
AC-16	Dunedin, South Road (Eastborne Street intersection)	74.8		55
SMA-11	Auckland, Campbell Road (Massey Avenue)	77.0	83.4	54
	Auckland, Smart Road	76.9	82.0	50
	Auckland, 294 Ellerslie Panmure Highway	75.4	83.4	60
	Auckland, 350 Ellerslie Panmure Highway	75.9	84.7	60
SMA-10	Hamilton, Te Rapa Road	77.5	85.1	60
	Hamilton, 425 Ulster Street	76.1	83.3	60
SMA-14	Hamilton, Wairere Drive (Quantum Lodge)	76.5	85.1	60
Macadam	Dunedin, Great King Street (Duke–Howe Street)	77.9	87.1	55
Slurry 3	Dunedin, Great King Street (Union–David Street)	76.4	86.6	55
	Dunedin, Anzac Avenue	76.0	85.8	55
	Dunedin, 333 Kaikorai Street	74.0	83.9	55
OGPA-14	Dunedin, 249 Taieri Road	76.1		55
	Tauranga, Turret Road (rest area)	76.6	85.4	50
	Tauranga, Fifteenth Avenue (opposite number 182/184)	76.0	86.1	50
OGPA-25	Tauranga, Takitimu Drive	83.0[b]	89.5[b]	85

Notes to Table 4.1:

a Noise levels were measured on two occasions: February 2005 and May 2005.

b Noise levels were recorded within an 80 km/h speed limit area; the results were excluded from analysis.

4.2 Adjusted for speed

Table 4.2 Noise levels from trial sites with speed adjustments

Road surface	Site location	Noise level (dBA)	
		Cars	Trucks
AC-10[a]	Lower Hutt, 359 Waiwhetu Road	73.5 73.4	82.5 84.8
	Lower Hutt, Wainui Road	73.8 72.6	83.9 84.6
	Lower Hutt, Cambridge Terrace (northbound)	73.8 72.8	84.8 84.7
	Lower Hutt, Cambridge Terrace (southbound)	74.2 73.1	84.5 84.5
	Lower Hutt, 408 Cambridge Terrace	73.4 72.6	83.2 84.6
AC-10 mean		**73.3**	**84.2**
AC-10	Auckland, 373 Neilson Street	74.0	84.3
	Auckland, 131 Abbots Way	73.0	83.0
	Auckland, 102 Great South Road	74.0	82.7
AC-10 mean		**73.7**	**83.3**
AC-14	Auckland, 50 Mangere Road	73.4	83.0
	Auckland, 117/119 Abbotts Way	72.3	84.6
	Auckland, 150 Church Street	72.7	85.0
AC-14 mean		**72.8**	**84.1**
AC-16	Dunedin, South Road	73.8	–
AC-16 mean		**73.8**	**–**
SMA-11	Auckland, Campbell Road (Massey Avenue)	76.0	82.6
	Auckland, Smart Road	76.0	82.0
	Auckland, 294 Ellerslie Panmure Highway	73.4	81.8
	Auckland, 350 Ellerslie Panmure Highway	73.9	82.9
SMA-11 mean		**74.8**	**82.3**
SMA-10	Hamilton, Te Rapa Road	75.5	83.5
	Hamilton, 425 Ulster Street	74.1	81.7
SMA-10 mean		**74.8**	**82.6**
SMA-14	Hamilton, Wairere Drive	74.5	83.5
SMA-14 mean		**74.5**	**83.5**
Macadam	Dunedin, Great King Street (Duke–Howe)	76.9	86.3
Macadam mean		**76.9**	**86.3**
Slurry-3	Dunedin, Great King Street (Union–David)	74.8	85.8
	Dunedin, Anzac Avenue	74.6	85.0
	Dunedin, 333 Kaikorai Street	72.4	83.1
Slurry-3 mean		**73.9**	**84.6**
OGPA-14	Dunedin, 249 Taieri Road	75.1	–
	Tauranga, Turret Road (rest area)	76.6	85.4
	Tauranga, Fifteenth Avenue	76.0	86.1
OGPA-14 mean		**75.9**	**85.7**
OGPA-25	Tauranga, Takitimu Drive	79.2	86.0
OGPA-25 mean		**79.2**	**86.0**

Notes to Table 4.2:

a Noise levels were measured on two occasions: February 2005 and May 2005.

5. Effect of rain on OGPA

A further effect that was partially examined in this project was the effect of rain on the noise generated by traffic on OGPA road surfaces. This was examined by monitoring the time gap between when the rain fell and when the noise measurements were made on the OGPA. OGPA is porous but it is thought that rain partially fills the pores with water. Additionally, it can take one or two days for the OGPA to dry thoroughly. This phenomenon was monitored at two sites, one surfaced with Flexiphalt, a 30 % voids surface, and the other site surfaced with TNZ P/11 mix, a 20 % voids surface. Noise levels (from light cars only) were measured to determine deviations in noise levels at different periods after rain had fallen. Measurements were planned four hours after rainfall, then two days (fifty hours) after, then seven days after. Unfortunately, at the time of the measurements, rain fell every two to four days, so it was impossible to measure at seven days (dry) after rain. Two attempts were made, resulting in two lots of measurements being made after two rainy periods, each taken fifty hours after the relevant rainfall. These measurements were compared with a reading made four hours after rain had fallen.

Figure 5.1 shows that the OGPA’s performance is significantly affected by rain, with the noise levels measured 4 hours after rain being 1.3–2.1 dBA higher than those measured 50 hours after rain. The material with the higher proportion of voids (the Flexiphalt) appears to drain more quickly than the 20% voids material (the TNZ P/11). The Flexiphalt ‘50 hours after rain’ values are 1.5 dBA and 2.1 dBA quieter than the reading made 4 hours after rain, compared to the readings from the 20% voids material, which were 1.3 and 1.9 dBA quieter.

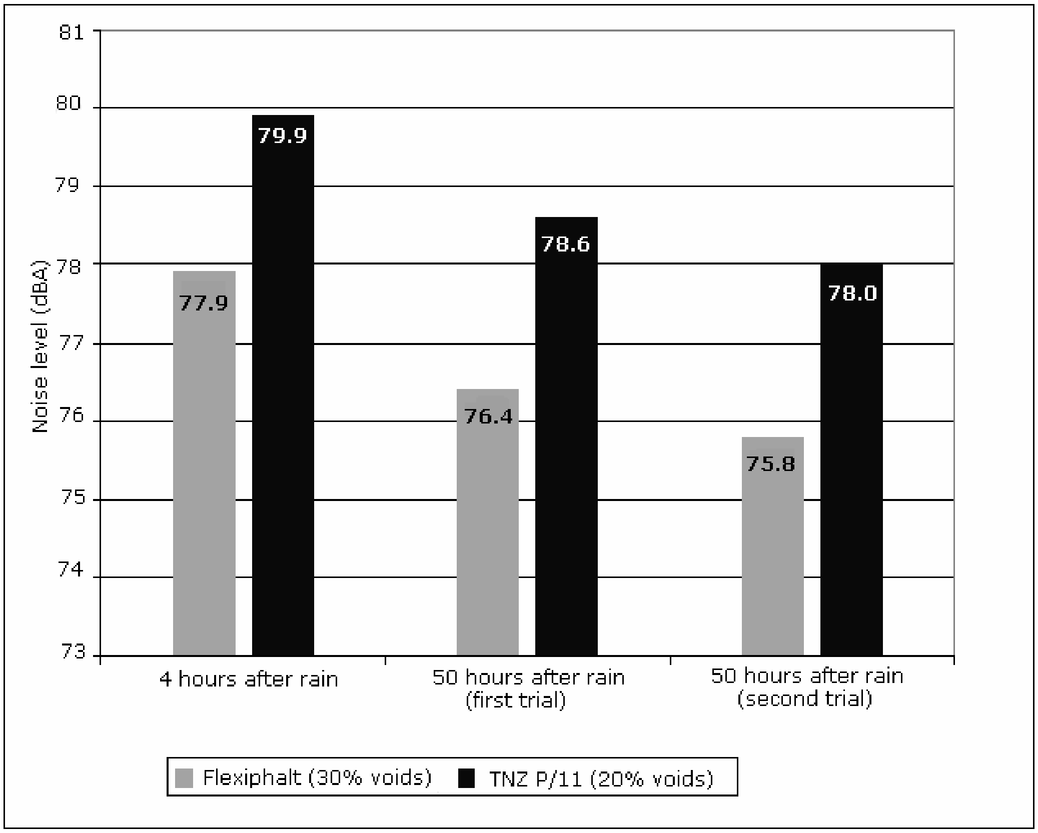

Figure 5.1 Effect of rainfall on noise levels in two grades of OGPA.

6. Discussion

6.1 Noise spectra diagrams

The table of results (Table 4.1 in Chapter 4), and Figure 6.1 and Figure 6.2 help to illustrate the consistency of the statistical pass-by technique.

Table 4.1 notes that the AC-10 in Lower Hutt was measured twice: first in February 2005 and then in May 2005. For the light vehicles, the two sets of readings differ by no more than 1.1 dBA and the means by 0.8 dBA. For the heavy vehicles, the two sets differ by up to 2.3 dBA (but 1 dBA is more typical) and the mean readings differ by about 0.9 dBA. A little more variation can be expected for trucks, given their differing sizes and the variability between loaded and unloaded vehicles.

Figure 6.1 and Figure 6.2 show the noise spectra for one set of measurements. The tyre noise components of the spectra, from about 800 Hz upwards, are consistent and of a very similar magnitude. These spectra have not been adjusted for the small difference in speeds at the sites.

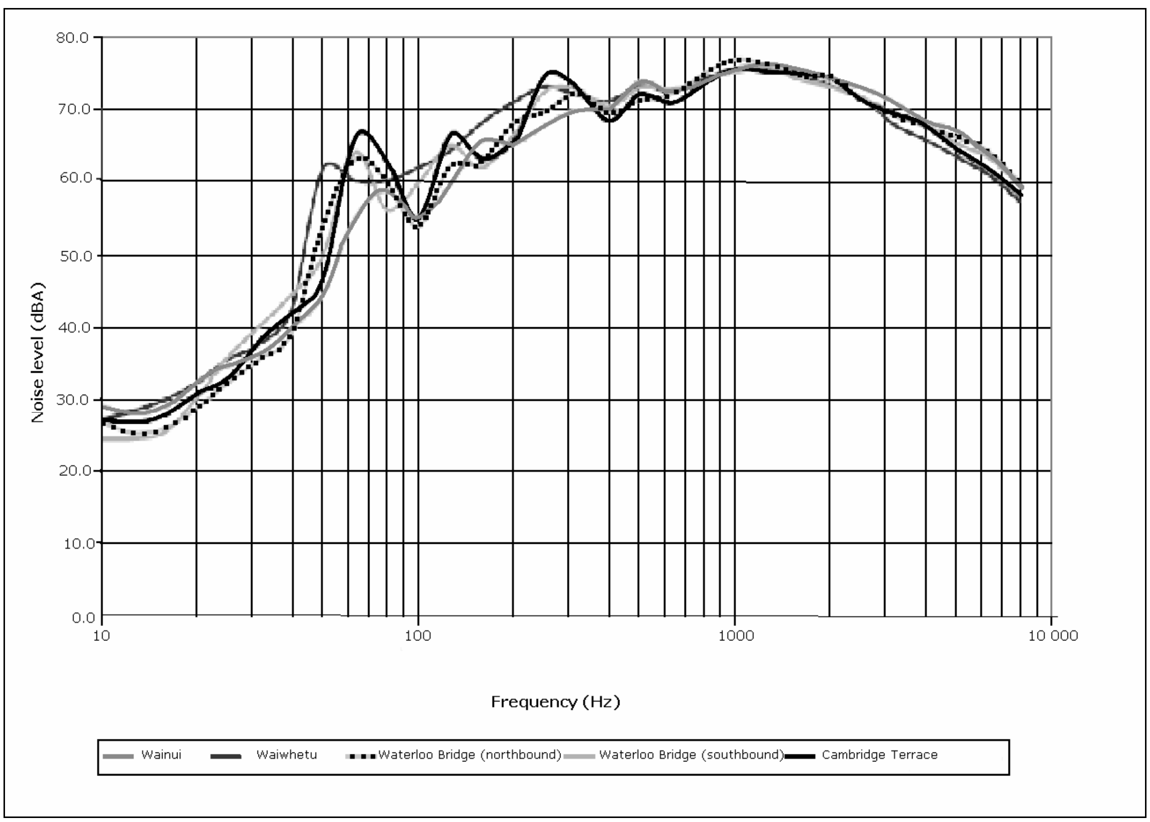

Figure 6.1 Noise spectra from cars on AC-10 at sites 4–8.

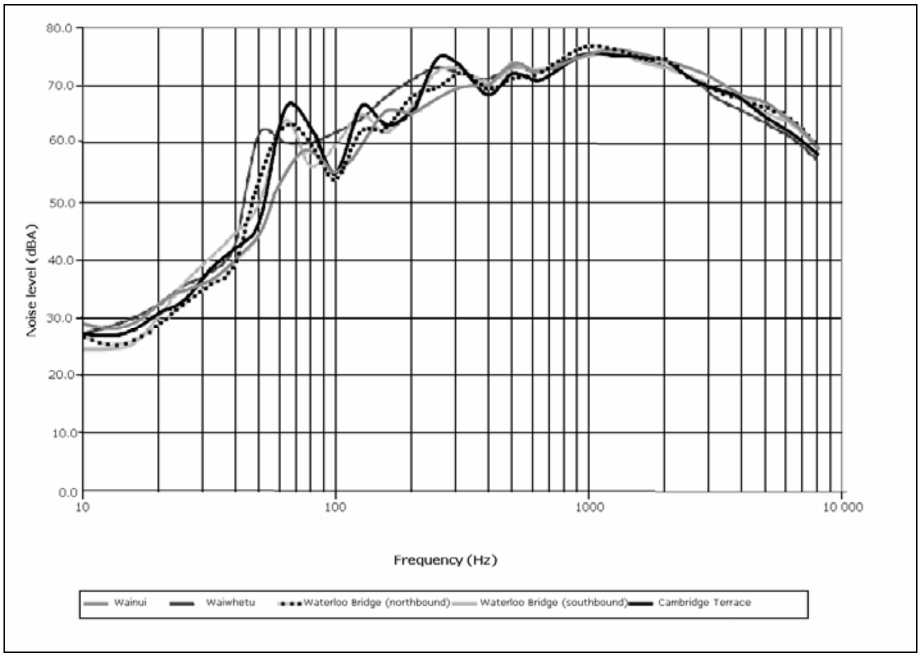

Figure 6.2 Noise spectra from trucks on AC-10 at sites 4–8.

Figure 6.3 shows the spectra for the three AC surfaces: AC-10, AC-14 and AC-16, showing that they have almost identical noise responses and noise levels.

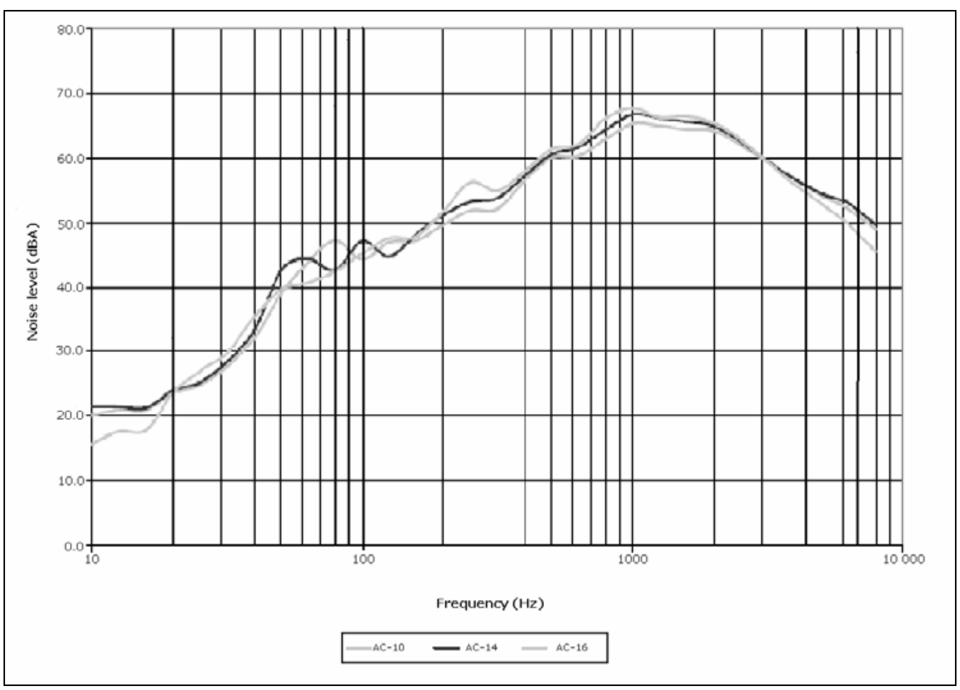

Figure 6.3 Noise spectra from cars AC-10, AC-14 and AC-16.

In contrast, Figure 6.4 and Figure 6.6 show significant differences between the spectra for cars on AC-10, SMA-11 and mmacadam (Figure 6.5 relates to trucks on AC-10 and SMA-11). The spectra for the SMA-11 and mmacadam have a more pronounced peak at 1000 Hz and lie above the AC-10 spectra in the 200 Hz to 2000 Hz region. This pattern is starting to approach a pattern similar to that of chipseal. This will be consistent with these two surface types having a significant texture and SMA having a significant proportion of larger stones.

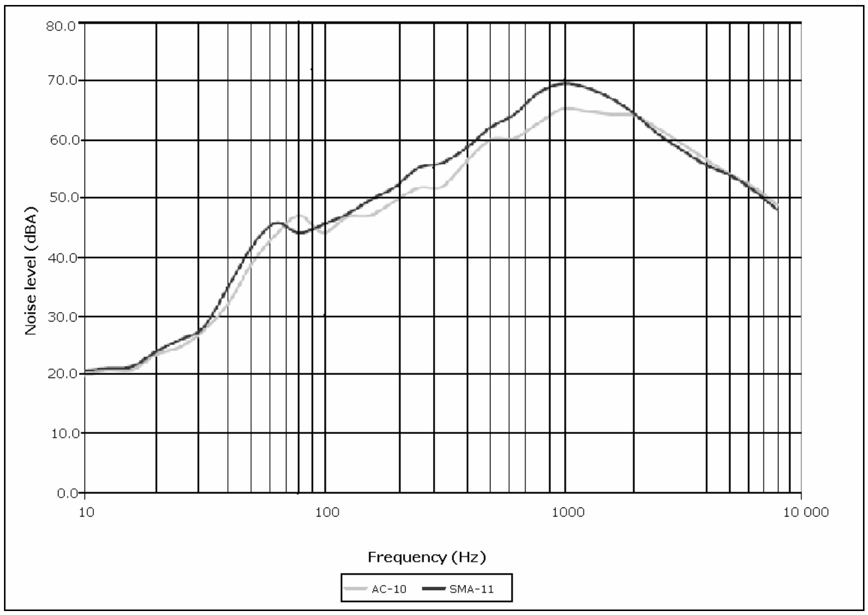

Figure 6.4 Noise spectra from cars on AC-10 and SMA-11.

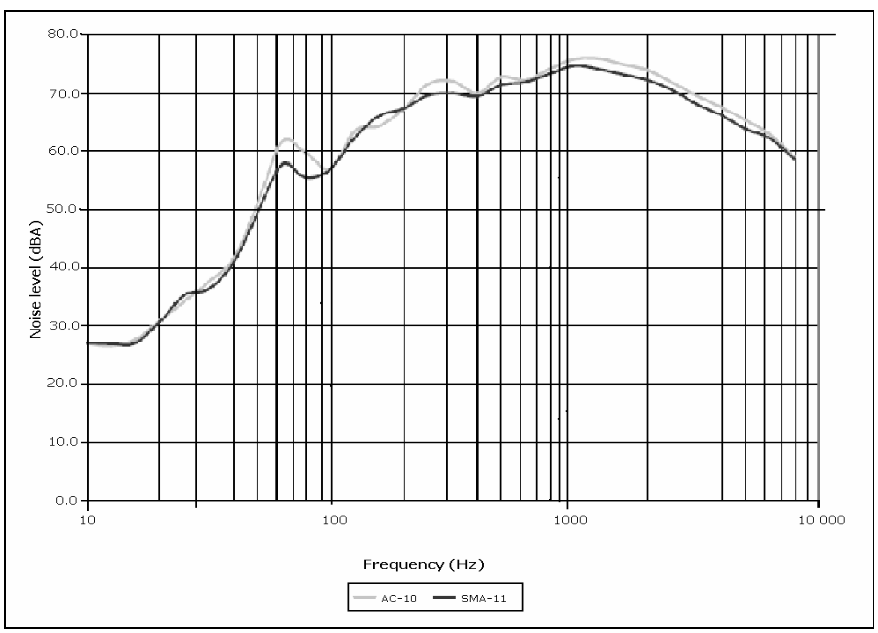

Figure 6.5 Noise spectra from trucks on AC-10 and SMA-11.

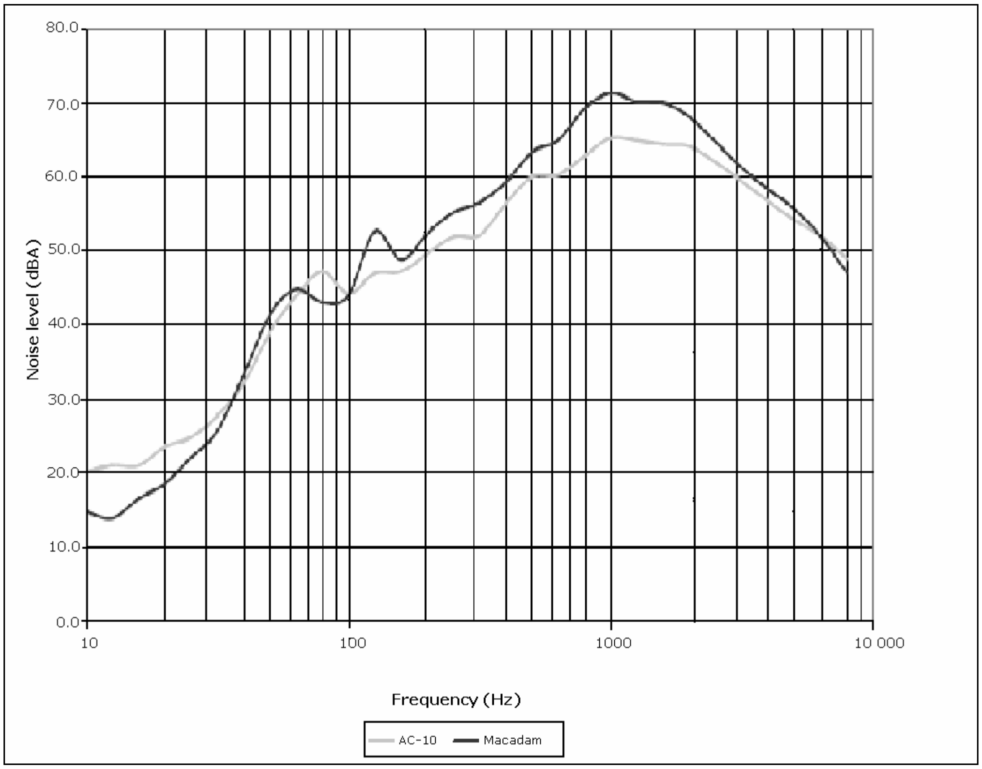

Figure 6.6 Noise spectra from cars on AC-10 and macadam.

Figure 6.7 and Figure 6.8 show that the traffic noise from type 3 slurry and OGPA road surfaces have spectra lying between that of AC-10, SMA-11 and macadam. Type 3 slurry has significant texture, as does the OGPA, given that it is made with 14 mm chip. The spectra shape of traffic noise from these surfaces is slightly more consistent with that arising from a chipseal-like texture.

In comparison to previous spectra for OGPA (from Dravitzki et al. 2006), the spectra of Figure 6.8 are very similar to that of the AC-10. In the previous spectra, the region around 2000 Hz was significantly less than that of AC-10. The OGPA of this current series had noise levels significantly higher than in the previous study. It may be that this OGPA has poor permeability so it provides a noise profile more similar to that of chipseal.

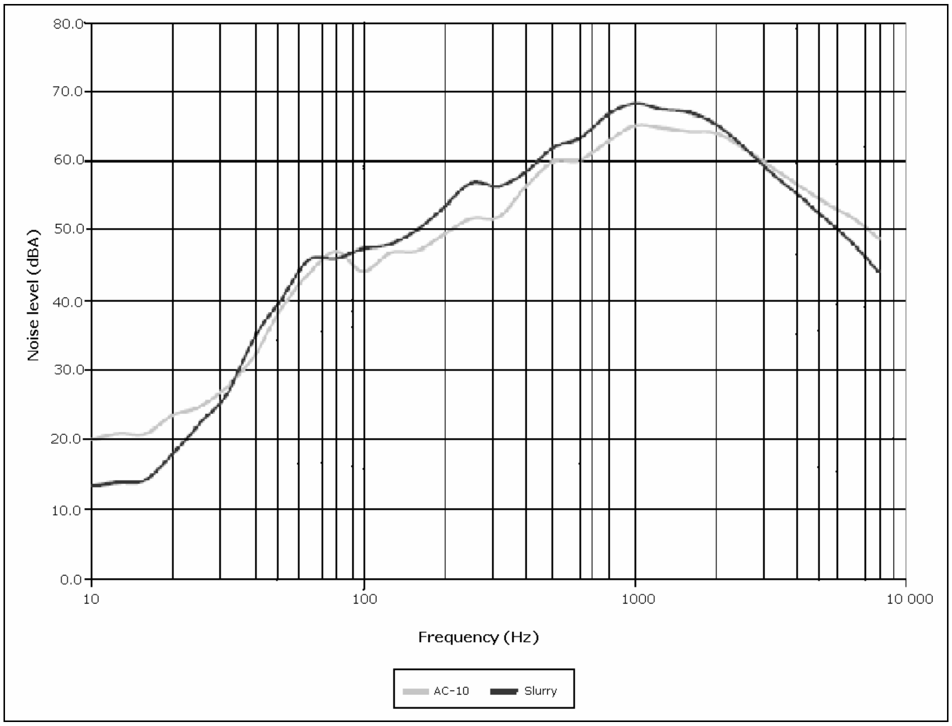

Figure 6.7 Noise spectra from cars on AC-10 and slurry.

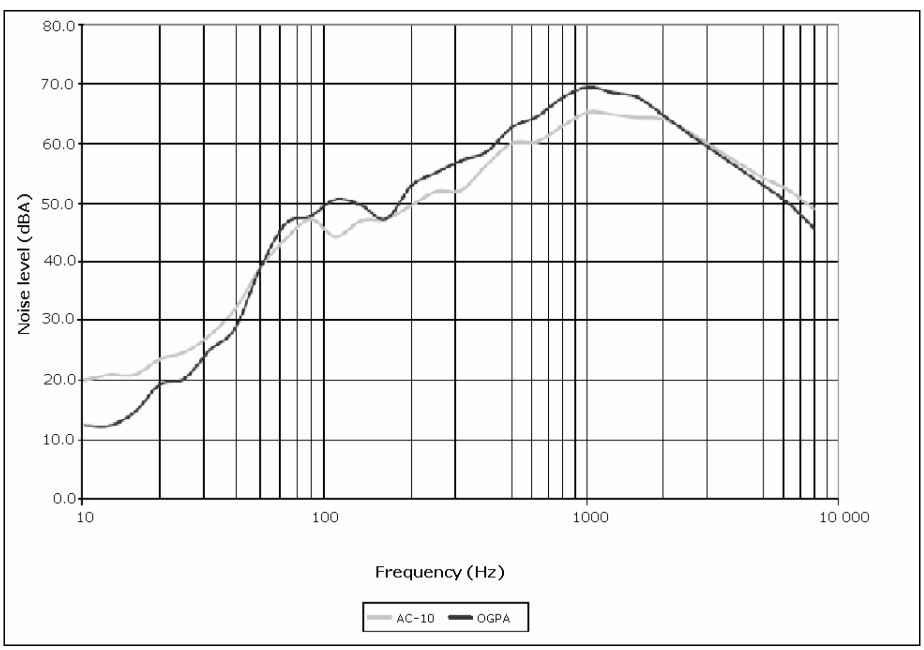

Figure 6.8 Noise spectra from cars on AC-10 and OGPA.

Figure 6.9 compares the spectra of all five bituminous mix surface types. The order of these surfaces for increasing texture is AC-10, slurry, OGPA, SMA-11 and macadam. As Figure 6.9 shows, the magnitude of the noise level and its progression to a more 'chipseal-like' profile follows this same order.

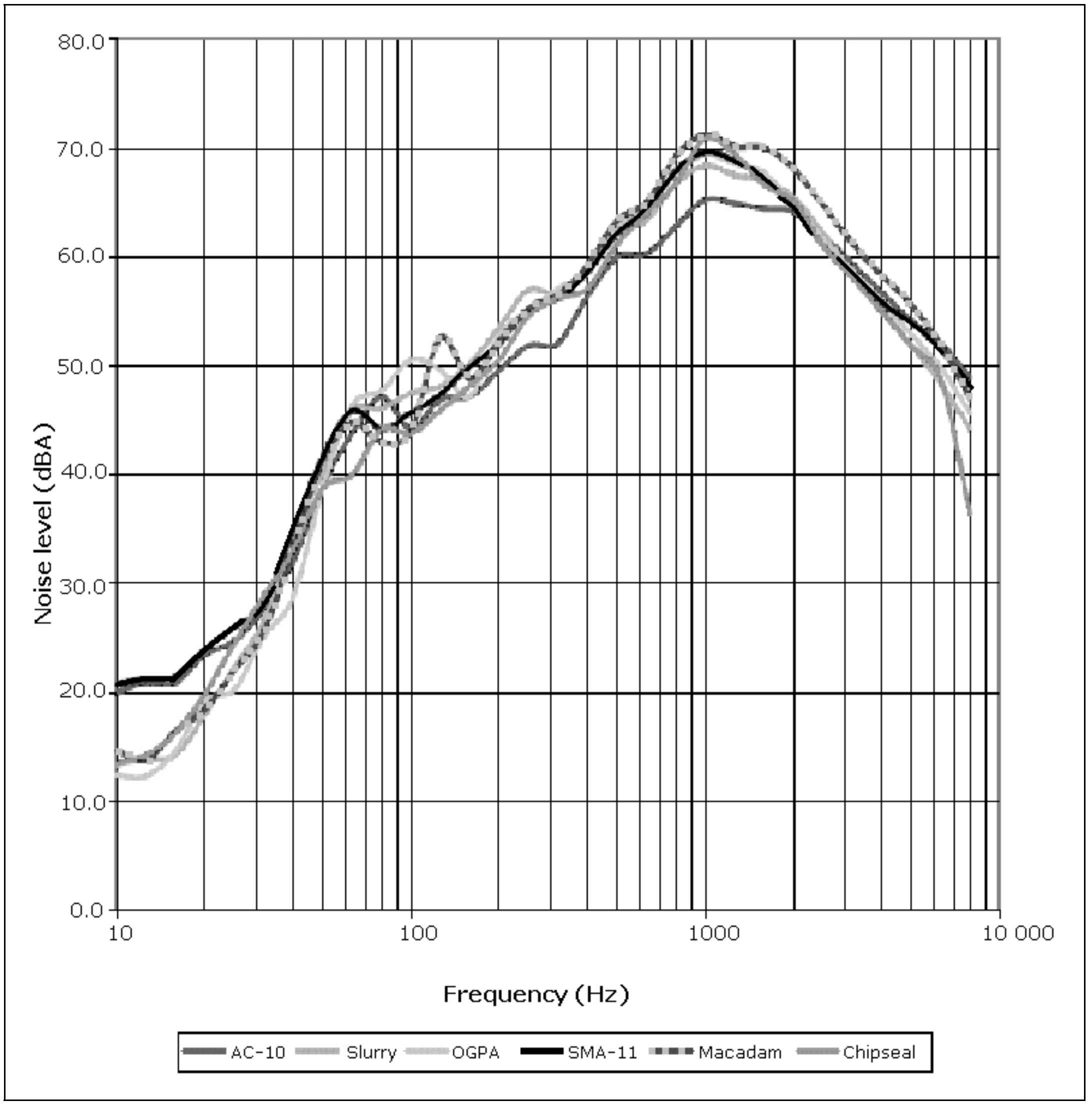

Figure 6.9 Noise spectra from cars on different surfaces.

Figures 6.1 to 6.9 are 1/3 octave band spectra, but for convenience, they are shown as a continuous line, as plotting them in the more technically correct 24 discrete points would make it more difficult to identify the individual spectra.

6.2 Surface correction

The road surface effect on noise relative to AC-10 is shown in Table 6.1 below, first as the actual difference and then rounded to the nearest 0.5 dBA.

Table 6.1 Noise effect of surface relative to AC-10 (dBA), actual and rounded values.

Surface type	Actual values (dBA)		Rounded values (to the nearest 0.5 dBA)	
	Cars	Trucks	Cars	Trucks
AC-10	Reference	Reference	Reference	Reference
AC-14	-0.5	-0.1	0	0
AC-16*	+0.5	0	0	0
SMA-10	+1.5	-1.1	+1.5	-1.5
SMA-11	+1.5	-1.9	+1.5	-2.0
SMA-14*	+1.2	-0.7	+1.0	-0.5
Macadam-14*	+3.3	+2.2	+3.0	+2.0
Slurry-3*	+0.6	+0.4	+0.5	+0.5
OGPA-14	+2.6	+1.5	+2.5	+1.5
OGPA-25*	+5.9	+1.8	+6.0	+2.0

* Only one surface of this type was measured.

Table 6.2 summarises Table 8 of the previous report (Dravitzki et al. 2006) on road surface noise effects.

Table 6.2 Noise effect of surface relative to AC-10 (dBA).

Vehicle	AC-10	Slurry	OGPA	Chipseals							
				#6	#5	#4	#2	#1	4/6	3/5	2/4*
Cars	Reference	+1	0	+3	+3	+3	+4	+6	+5	+6	+4
Trucks	Reference	-3	-2	-2	0	-2	+1		0	+1	N/A

* Only one surface of this type was measured.

Table 6.3 shows the results obtained from Dravitzki & Kvatch 2004, which examined the noise effects of several specialised surfaces used in motorway situations.

Table 6.3 Noise effect of specialised road surfaces (dBA).

Surface	Relative to conventional OGPA		Relative to AC-10*	
	Cars	Trucks	Cars	Trucks
Dual layer 70 mm OGPA	-2.3	-1.9	-2.5	-4.0
Dual layer 50 mm OGPA	-1.9	-1.4	-2.0	-3.5
Macadam	+4.0	+2.0	+4.0	0
Ultra-thin asphalt	+2.7	+1.7	+2.5	0

* Adjusted relative to AC-10 by 0 dBA for cars and -2 dBA for trucks, and rounded to closest 0.5 dBA.

Some general trends arise from Tables 6.1 to Table 6.3. Relative to the reference surface of AC-10, as the surface becomes more textured and irregular:

- the noise level for cars increases;
- the noise level for trucks first decreases for small increases in texture, then increases as texture becomes larger; and
- porous surfaces show some additional effects.

Texture is used here in the more generic sense of size and irregularity than simply texture depth, which is a measurement of average texture height by a particular methodology. It has been found previously (Dravitzki et al. 2006) that a simple texture depth/noise effect relationship was not consistent, particularly for two-coat seals. Noise effects were much stronger than average texture depth would predict. The high irregularity in the surface, which occurs because the two-coat system does not allow chips to rotate so they can lie on their average greatest dimension, was believed to be a significant factor.

The overall trends broadly fit the international literature (such as the Nordic model (Nordic Council of Ministers 1996)) although in a number of instances (e.g. the larger chipseals), the effect appears more pronounced.

Cars and trucks appeared to show different trends:

- In cars, the noise effect increased with texture.
- In trucks, noise levels first decreased as texture grew greater, but then increased as the texture continued to increase.

This difference arises primarily from cars and trucks having different behaviours on the reference surface of AC-10. The difference in noise levels between cars and trucks is greatest for this surface. It is believed that AC, with its almost flat surface that is substantially free of voids, interacts with the comparatively stiff truck tyre with its large flat tread pattern to generate comparatively higher noise levels. As road surface texture slightly increases above that of AC-10, a small amount of texture initially reduces this flat-on-flat interaction so that the noise level falls.

The surface effects on noise shown in Tables 6.1 to 6.3 do not align with each other in all cases. This can be expected for at least two reasons. First, the number of samples is small and secondly, the road surface laid may not fully achieve its intended design (defined for highways in New Zealand by Transit New Zealand's specifications, such as TNZ P/9: Construction of Asphaltic Concrete Paving (1975), or TNZ P/11: Open Graded Porous Asphalt (2007)). Several of the road surfaces included in this project have quite specialised applications For example, it is not uncommon for SMA, which should appear similar to OGPA, to be incorrectly laid so that it is a better match to a smoother surface such as AC.

6.3 Recommended surface corrections

6.3.1 Recommended overall surface effect corrections

Table 6.4 provides a set of recommended surface effect corrections for use with New Zealand roads. It is a consolidation of the previous tables, and therefore a consolidation of results from this study and the previous study (Dravitzki et al. 2006). Some adjustments have been made to align with the readings better; the rationale for the adjustments is described below.

Table 6.4 Recommended New Zealand road surface corrections, relative to AC-10 (dBA).

Surface category	Surface type	Cars	Trucks
Asphalt – dense graded	1 0mm	Reference	Reference
	14 mm	0.0	0.0
	16 mm*	0.0	0.0
OGPA	OGPA-14, 20%voids	0.0	-2.0
	OGPA-14, 30% voids	-2.0	-3.0
	70 mm double-layer, Wispa	-2.0	-4.0
	OGPA-25*	+3.5	-1.0
Capeseal	#2/Type 3*	+3.0	+1.0
	#3/Type 2*	+2.0	-1.0
	#4/Type 1*	0.0	-1.0
SMA	10	+1.5	-1.5
	11	+1.5	-1.5
	14*	+1.5	-1.5
Slurry seal	Type 3*	+1.0	-1.0
Macadam	–	+3.0	0.0
Chipseal	Grade 6 (7 mm)	+3.0	-2.0
	Grade 5 (10 mm)	+3.0	-2.0
	Grade 4 (12 mm)	+3.0	-2.0
	Grade 3 (16 mm)	+4.0	+1.0
	Grade 2 (19 mm)*	+6.0	+1.0
Two-coat seals	Grade 4/6 (12/7 mm)	+5.0	+1.0
	Grade 3/5 (16/10 mm)	+6.0	+1.0
	Grade 3/6 (16/7 mm)	+6.0	+1.0
	Grade 2/4 (19/12 mm)*	+6.0	+1.0

* Results indicative only as data have been taken from a very small sample.

6.3.2 OGPA

The noise effects of the OGPA have been examined previously, both in other work and in Dravitzki et al. 2006. Wassilief (1995) concluded that the noise effects of standard 20 % voids material at 30 mm to 40 mm thickness arise primarily from texture. However, reference to the test samples of the laid material showed that both were apparently 18 to 20 % voids, so permeability effects were less evident in those samples. Wassilief's work does show that the effect of permeability in noise reduction is often given too much weight, and both permeability and texture are important for reducing noise. A noise effect of 0 to +1 for cars and -2 for trucks derived from measurements made on a number of surfaces fits this theory.

The results from OGPA in Table 6.1 are only partly consistent with previous experience. OGPA-14 has a maximum chip size of 14 mm and OGPA-25 has a maximum chip size of 25 mm. The differences in noise between the 14 and 25 mm grades are explicable in terms of the chip sizes (comparable with Grade 5 and Grade 2 chip in Table 6.2). However, the OGPA-14 has a stronger surface effect than previous measurements. In conjunction with Figure 6.8, it was identified that the spectral content indicated differences compared to OGPA at other sites. All the OGPA values in Table 6.1 are from measurements made in Tauranga. Therefore, Table 6.4 uses the previous OGPA measurements as being more applicable but still uses the difference between OGPA-14 and OGPA-25, found at Tauranga, to set a level for OGPA-25.

6.3.3 Slurry seal

The noise effect of slurry seal as shown in Table 6.2 appears overstated, given the similarity between slurry seals and AC, and the data of Table 6.1. Type 3 slurry has a bit more texture than AC-10. A value of +1 dBA for cars and -1 dBA for trucks has therefore been assigned to slurry seal.

6.3.4 SMA

In terms of road surface type, SMA has the appearance of OGPA and a texture equivalent to some of the smaller chipseals. From the findings for increasing aggregate chip sizes shown in Table 6.1, no conclusive trend can be drawn. However, based on the data in Table 6.1, and corresponding data on OGPA and Grades 4, 5 and 6 chip in Table 6.2, values of +1.5 dBA for cars and -1.5 dBA for trucks are assigned to SMA for all grades.

6.3.5 Macadam

Macadam has a surface appearance lying between dense asphalt and SMA. However, Table 6.1 indicates a value of +3 for cars and +2 for trucks while Table 6.3 indicates +4 for cars and 0 for trucks. Both are based on only one sample and both indicate a surface noise effect greater than that of SMA. A value of +3 dBA for cars and 0 dBA for trucks is a conservative compromise from these two and reflects the context of macadam within the range of surface types better.

7. Comparing surface effects for New Zealand with those of other countries

7.1 Nordic model

The Nordic model (Nordic Council of Ministers 1996) does not give separate surface effects for cars and trucks directly. Instead it provides surface effects for three traffic mixes that depend on the proportion of heavy vehicles, and three speed ranges:

- traffic mixes: 0–5%, 6-19% and 20–100% heavy vehicles;
- speed ranges: 0–60 km/hr, 61–80 km/hr and 81–130 km/hr.

The reference surface is AC but the mix size is 12–16 mm compared to AC-10 (10 mm and less).

The Nordic model predicts that the surface effect increases in magnitude, either more positive or more negative, as the speed increases.

Table 7.1 has been deduced as the likely surface effects for cars and heavy vehicles separately, based on the combined effect as set out in Appendix 1 of the Nordic model.

Table 7.1 Surface effects compared to AC-10 deduced from the Nordic model (Nordic Council of Ministers 1996).

Surface	Less than 60 km/h		80–130 km/h	
	Cars	Trucks	Cars	Trucks
AC-10	Reference	Reference	-1	-1
Large chip	+1	0	+2	0
Small chip	0	0	-1	0
Two-coat	0	0	0	-1
SMA	-1	0	-1	-1
OGPA (14–16 mm) old (>2 years)	0	0	-1	-1
OGPA (14–16 mm) 1–2 earyears	-1	-1	-1	-3
OGPA (8–10 mm) old (>2 years)	0	0	-2	-2
OGPA (8–10 mm) 1–2 years	-1	-1	-3	-3

7.2 AUSTROADS

The Australian Asphalt Pavements Association (APAA)/AUSTROADS publication 'Guide to the selection of road surfacings' (AUSTROADS 2003) provides a table of road surface noise effects for several surface types. They provide a combined effect only, which is shown in Table 7.2 below. The publication does not identify whether these effects are for open road speeds only, or if they are for both urban and open road speeds. For comparison, Table 7.2 also contains a combined effect for 5 % and 10 % heavy traffic using the data of this current report.

Table 7.2 Surface effects deduced from the AUSTROADS information.

Surface	AAPA / AUSTROADS	Current report: New Zealand		
		0 % heavy	5 % heavy	10 % heavy
Coarse chipseal #2 or two-coat	–	+6.0	+5.0	+4.3
Spray seals ≥10 mm	+4.0	+4.0	+3.3	+2.8
Spray seals ≥7 mm	+2.0	+3.0	+2.0	+1.3
DGA	0.0	0.0	0.0	0.0
OGPA	-3.0	0.0	-0.5	-0.8
SMA	-1.0	+1.5	+0.7	+0.3
Slurry	0.0	–	–	–

Allowing for the uncertainty as to the circumstances in which the road surface noise effects reported by APAA/AUSTROADS apply, the effects are reasonably similar to those found for New Zealand in this current report.

Comparing road surface effects, as has been done in Table 7.2, is complicated by these effects being expressed in relation to DGA, as DGA is not an exact match from one country to another. The comparison is therefore made between 'differences relative to dense graded asphalt' as made in each country and the appearance of the table of surface effects is influenced by the nature of the DGA relative to other surfaces for each country.

A better understanding can be achieved by comparing the pattern shown by a number of the surfaces relative to each other. As was shown by Figure 2.1, New Zealand DGA contains considerable fines and has a low surface texture. The New Zealand data placed the noise effect of dense asphalt close to that of OGPA and well below the noise effect of very coarse chipseals. The Australian data, in comparison, appears to place the noise effect of DGA a little more centrally. A consequence is the position of SMA in the table. This Australian table assigns a value of -1 dBA relative to DGA; the New Zealand value is +1.5 dBA relative to DGA. However, both tables have the noise effect from SMA 2.0 dBA or 1.5 dBA greater than the noise effect of OGPA.

8. Conclusions

A table of differences in effect of road surfaces on traffic noise has been prepared (Table 8.1). This table has separate effects for cars and heavy vehicles. The table is believed to be valid for speeds from 50 to 100 km/h. It is recommended that this table be used when calculating noise or selecting road surfaces.

Table 8.1 Recommended New Zealand road surface corrections, relative to AC-10 (dBA).

Surface category	Surface type	Cars	Trucks
Asphalt – dense graded	1 0mm	Reference	Reference
	14 mm	0.0	0.0
	16 mm*	0.0	0.0
OGPA	OGPA-14, 20%voids	0.0	-2.0
	OGPA-14, 30% voids	-2.0	-3.0
	70 mm double-layer, Wispa	-2.0	-4.0
	OGPA-25*	+3.5	-1.0
Capeseal	#2/Type 3*	+3.0	+1.0
	#3/Type 2*	+2.0	-1.0
	#4/Type 1*	0.0	-1.0
SMA	10	+1.5	-1.5
	11	+1.5	-1.5
	14*	+1.5	-1.5
Slurry seal	Type 3*	+1.0	-1.0
Macadam	–	+3.0	0.0
Chipseal	Grade 6 (7 mm)	+3.0	-2.0
	Grade 5 (10 mm)	+3.0	-2.0
	Grade 4 (12 mm)	+3.0	-2.0
	Grade 3 (16 mm)	+4.0	+1.0
	Grade 2 (19 mm)*	+6.0	+1.0
Two-coat seals	Grade 4/6 (12/7 mm)	+5.0	+1.0
	Grade 3/5 (16/10 mm)	+6.0	+1.0
	Grade 3/6 (16/7 mm)	+6.0	+1.0
	Grade 2/4 (19/12 mm)*	+6.0	+1.0

* Results indicative only as data have been taken from a very small sample.

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Road Surface Effects on Traffic Noise: Stage 3 – Selected Bituminous Mixes

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Research Report 326