A Follow Up Investigation of the Long Term Road Traffic Noise Attributes of Some Pavement Surfaces in Townsville

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ABSTRACT

This paper presents a follow up investigation of the noise attributes of several pavement surfaces currently in service in and around Townsville. The investigation aimed to examine the acoustic performance of the set of pavement surfaces over time. A previous similar investigation, which was reported to the 2004 AAS Annual Conference, involved two extensive data collection exercises which were conducted in 2002 and 2003. In the present investigation more data were collected in 2004. Analyses of the data produced values of a parameter known as the Statistical Passby Index which was applied to quantifying the acoustic performance of the pavement surfaces over time. It was found that the acoustic attributes of most of the pavement surfaces remained reasonably stable over the two year period from 2002 to 2004. This was not, however, always the case and some explanations for variant behaviour are presented in the paper. In further exploring these observations, a subset of the 2004 data set was compared to a theoretical model of pavement surface noise generation developed by the first Author several years ago. In addition this data set was compared to some empirical data also previously collected by the first Author elsewhere in Australia. These comparisons facilitated explanations of the acoustical attributes of the Townsville pavement surfaces.

INTRODUCTION

The present paper deals with another investigation of the acoustic attributes of several pavement surfaces in Townsville. It follows on from the work reported in Samuels (2004 A) concerning similar investigations that involved data collection in August 2002 and December 2003. A specific objective of the investigation reported in the present paper was to reinvestigate the noise attributes of the various pavement surfaces that had been studied previously, with particular emphasis on examining the acoustic performance of these pavement surfaces over time. Data collection for the latest investigation was undertaken in December 2004.

As with Samuels (2004 A), the work reported herein comprises one component of a more extensive study being undertaken by the authors for the Queensland Department of Main Roads (QDMR) which is directed at investigating the long term noise attributes of pavement surfaces in Queensland.

DATA COLLECTON AND ANALYSIS

Data collection

The experimental design of the latest investigation was the same as that of Samuels (2004 A) and involved collecting samples of passby noise data from three vehicle types (cars, medium trucks and heavy trucks) on eight pavement surfaces. Data had been collected in 2002 on five of these sites and in 2003 on all eight. Note that Samuels (2004 A) only reported on the 2002 and 2003 data from five of the eight sites. The latest data were collected according to the statistical passby technique, which involved the simultaneous measurement of the noise and the speed of individual vehicles in the traffic stream as they passed by each measurement location (ISO 1997). Reiterating from Samuels (2004 A), roadside measurement locations were set up for this purpose at the eight sites. The noise data were collected at all sites by the first author with a Bruel and Kjaer Type 2260 precision Sound Level Meter, the calibration of which was at specification throughout. Speed data were collected at all sites by an assistant utilising a radar speed meter situated adjacent to the noise measurement station. This speed meter was concealed as far as possible so as not to influence driver behaviour at or near to the measurement station. During all the measurements weather conditions were fine and mild throughout, with occasional very light breezes. At all five sites the passby noise levels (dB(A)) and speeds (km/h) were measured repeatedly for around 80 cars, 20 medium trucks and 20 heavy trucks.

Information about the sites, which are located in and around metropolitan Townsville, appears in Table I below. Note that the Site Identifiers were specified to be compatible with other similar studies undertaken recently by the authors for QDMR. They also relate to the pavement surface types which are as follows.

SMAC: Stone Mastic Asphaltic Concrete

DGAC: Dense Graded Asphaltic Concrete

CS: Chip Seal

Table I. Sites included in the latest investigation

Site Location	Pavement surface type	Site Number
Abbott Street	Boral Novachip	SMAC 5
	Pioneer Hushphalt	SMAC 6
	Boral LoNoise	SMAC 7
	DGAC	DGAC 8
Boundary Street	Boral LoNoise	SMAC 8
Bruce Highway	Pioneer SMA 14	SMAC 9
	Boral SMA 14	SMAC 10
	10 mm CS	CS 4

Data analysis

All of the statistical passby data were collated and analysed in accord with the established, scientifically based procedures adopted in Samuels (2004 A). Parameters involved in the analysis included pavement surface type, vehicle type, vehicle speed and vehicle trajectory to microphone distance. From there, the measured noise levels were applied to calculating a set of Statistical Passby Indices, or SPBIs (ISO 1997). Further details about the SPBI are given in Samuels (2004 A) and in Samuels and Parnell (2001 and 2003) and will not be repeated here. The SPBI is defined below in Equation 1 (ISO 1997).

$$SPBI = 10\mathrm{Log}\,(W_1 \times 10^{L1/10} + W_{2a}(V_1/V_{2a}) \times 10^{L2a/10} + W_{2b}(V_1/V_{2b}) \times 10^{L2b/10}) \quad (1)$$

Where

SPBI = Statistical Passby Index of a given pavement surface (dB)

L_x = Passby noise level of Vehicle Type X on the given pavement surface at a reference speed of V_x and at a reference distance of 7.5m (dB(A))

W_x = Proportion of Vehicle Type X in the traffic (-)

V_x = Reference speed of Vehicle Type X (km/h)

There are three vehicle types involved and these are Cars (1), Medium Trucks (2a) and Heavy Trucks (2b). For the purposes of this paper the SPBIs were calculated for speed conditions, known as "high", wherein cars and trucks were assigned the reference speeds of 110km/h and 85km/h respectively. A key feature of the SPBI is that it includes the influence of traffic composition and this is achieved through the parameters W_1, W_{2a} and W_{2b}. Thus in order to calculate the SPBI it is necessary to specify the values of these three parameters. This specification was made after consultation with relevant staff of QDMR and on the basis of the present authors' extensive experiences in the road industry. What ensued was a set of traffic conditions that comprised 90% cars, 5% medium and 5% heavy trucks.

THE PAVEMENT SURFACE EFFECTS ON TRAFIC NOISE OVER TIME

The Statistical Passby Indices

The SPBI data are presented in Table II and Figure 1. Also shown in Table II are the SPBIs determined from the December 2003 and August 2002 data and these will be discussed subsequently. Inspecting the results from the December 2004 data in both Table II and Figure 1 indicates that the total variation in traffic noise from the quietest pavement surface (SMAC 7: LoNoise in Abbott Street) to the loudest (CS 4) was a considerable 5.5 dB. Again it is useful to consider these variations relative to DGAC, so this has been done in Table III. It is very apparent here that in December 2004 the lowest traffic noise levels would occur on the Abbott Street trial pavement surfaces, with the LoNoise and Hushphalt being marginally quieter than the Novachip.

Both these LoNoise and Hushphalt pavement surfaces produced around 3.2 dB reductions in traffic noise compared to DGAC in December 2004 and these are both useful and readily noticeable. However at that time the LoNoise pavement surface in Boundary Street would produce a negligible difference in traffic noise from the DGAC surface upon which it was overlaid and this observation will be explored subsequently. In addition it may be observed that both the SMA 14s in the Bruce Highway would produce negligible changes in traffic noise. Overall, all these results are consistent with those of Samuels (2004 B) for a set of pavement surfaces in South-East Queensland.

Table II. Statistical passby indices for “high” speed, 90-5-5 traffic conditions

Location	Site	Pavement surface type	Statistical Passby Index (dB)		
			Data collected in December 2004	Data collected in December 2003	Data collected in August 2002
Abbott Street	SMAC 5	Novachip	79.5	79.4	80.8
	SMAC 6	Hushphalt	78.6	80.1	79.4
	SMAC 7	LoNoise	78.5	78.4	76.9
	DGAC 8	DGAC	81.7	82.2	82.0
Boundary Street	SMAC 8	LoNoise	81.2	81.7	78.7
Bruce Highway	SMAC 9	Pioneer SMA 14	81.4	81.2	-
	SMAC 10	Boral SMA 14	81.7	80.8	-
	CS 4	10 mm CS	84.0	83.7	-

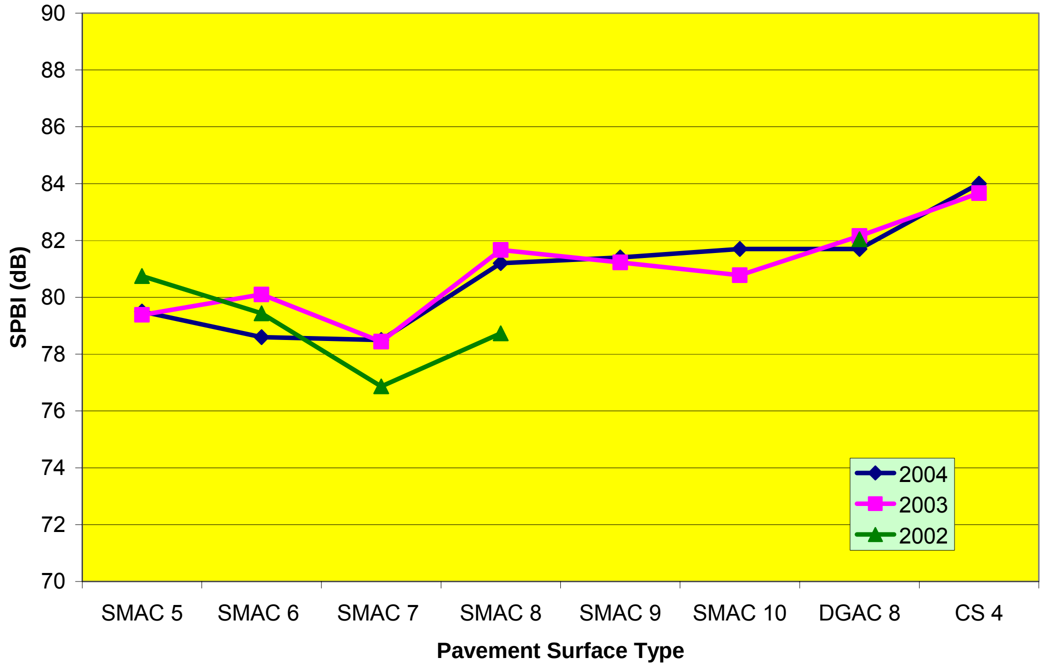

Figure 1. SPBIs for all sites as determined in December 2004, December 2003 and August 2002

Table III. Variations in Statistical Passby Indices relative to DGAC

Location	Site	Pavement surface type	SMAC or CS SPBI - DGAC SPBI (dB)		
			Data collected in December 2004	Data collected in December 2003	Data collected in August 2002
Abbott Street	SMAC 5	Novachip	- 2.2	- 2.8	- 1.2
	SMAC 6	Hushphalt	- 3.1	- 2.1	- 2.6
	SMAC7	LoNoise	- 3.2	- 3.8	- 5.1
Boundary Street	SMAC 8	LoNoise	- 0.5	- 0.5	- 3.3
Bruce Highway	SMAC 9	Pioneer SMA 14	- 0.3	- 1.0	-
	SMAC 10	Boral SMA 14	0.0	-1.4	-
	CS 4	10 mm CS	2.3	1.5	-

The relative and absolute acoustic performance of the pavement surfaces over time

The SPBI data presented in the tables and diagram above were revisited to illustrate what effects the outcomes would have on traffic noise. Note that the observations and interpretations that now follow are based on the premise that the "high" speed, 90-5-5 composition traffic conditions remained constant over the time periods involved. Considering firstly Abbott Street, the traffic noise levels on the DGAC would have remained essentially constant over the total period from August 2002 to December 2004. However the traffic noise would have decreased slightly on the Novachip (SMAC 5) over the period between August 2002 and December 2003. Over the subsequent year to December 2004, the traffic noise levels on this pavement surface would have remained stable. On the Hushphalt (SMAC 6) there would have been very small, generally negligible increases in traffic noise over the period from August 2002 to December 2003. In the subsequent year to December 2004, the traffic noise levels on the Hushphalt would have reduced to a level marginally below those of August 2002. Finally there would have been a small increase of 1.5 dB(A) in the traffic noise on the LoNoise over the period from August 2002 to December 2003. However in the subsequent year to December 2004, the traffic noise on this pavement would have remained stable.

In Boundary Street, the traffic noise on the LoNoise would have increased by a considerable 3 dB(A) over the period from August 2002 to December 2003. Such an increase is effectively equivalent to the increase that would occur if the traffic volume doubled over the period and all other relevant factors remained constant. A precise explanation as to why this increase took place has not been possible to date since it would require further scientific investigations. However Samuels (2004 B) reasonably argued that it was the result of some changes that have occurred in the LoNoise pavement surface over the period. Perhaps the pavement surface compacted further over time or became clogged with foreign matter. Maybe the same effects also occurred in the Abbott Street LoNoise pavement surface in the time period between August 2002 and December 2003, but to a somewhat lesser extent than in Boundary Street. This would offer a plausible explanation for the slightly lower increase in traffic noise on the Abbott Street LoNoise compared to Boundary Street over the same period. Nevertheless, in the subsequent year to December 2004, the traffic noise levels on the Boundary Street LoNoise pavement surface would have remained stable. That is the traffic noise levels on both LoNoise pavement surfaces in Abbott and Boundary Streets would have increased from August 2002 to December 2003 remained stable in the subsequent year to December 2004.

Along the Bruce Highway, the traffic noise on the Pioneer SMA 14 (SMAC 9) would have remained stable over the year from December 2003 to December 2004. Similarly, the traffic noise on the CS would have also remained stable over that year. Over the same period the traffic noise on the Boral SMA 14 (SMAC 10) would have increased by a marginal and generally negligible 0.9 dB(A). Overall it may be concluded that the acoustic attributes of the three pavement surfaces in the Bruce Highway have remained constant over the year from December 2003 to December 2004.

PAVEMENT SURFACE TEXTURE EFFECTS

As mentioned in Samuels (2004 A), the macrotexture depths of the pavement surfaces in Abbott and Boundary Streets were measured and provided by QDMR during the 2003 data collection period. Since it has been well established that pavement surface macrotexture has a considerable effect on the generation of traffic noise (Samuels 1982, Samuels and Glazier 1990, Sandberg and Ejsmont 2002), the SPBIs determined from the 2003 data were plotted against these macrotexture depths in Samuels (2004 A). This was followed by some observations of the acoustic performances of the pavement surfaces involved.

In exploring these observations a little further, the passby noise data for cars determined in the 2003 investigation were compared to the pavement surface macrotextures as shown in Table IV. From there these data were overlaid on the plot of Figure 2 which was extracted from Samuels (1996). This particular plot shows the spread of passby noise levels of cars determined previously on a variety of pavement surfaces in New South Wales and Victoria. It also shows two curves which were produced from a theoretical and empirically based model of tyre/road noise generation developed earlier by the first Author and presented in Samuels (1994) and as set out below in Equation 2.

$$SPL = A + B \log V + C \log(26600\ M^2 + 45000/M) \qquad (2)$$

Where SPL = Passby noise level (dB (A))

V = Vehicle speed (km/h)

M = Mean depth of road surface macrotexture (mm)

A, B and C = Regression coefficients.

Initially it is apparent in Figure 2 that the data point for DGAC 8 lies reasonably close to the predicted curve, as would be expected. Secondly it would seem that, for cars at least, the SMAC 8 pavement surface was behaving acoustically similar to a DGAC. SMACs 5, 6 and 7 produced the lowest car noise levels. The car noise levels on these three pavement surfaces are similar in Figure 2 to those of the OGACs. Again SMAC 7 seemed to behave acoustically in a different manner from SMACs 5, 6 and 8. As speculated in Samuels (2004 A), this apparent difference may be due to the internal structure of the SMAC 7 (i.e. the apparent porosity) which could differ from the other SMACs in such a manner as to emulate the noise reducing properties of the other pavement surfaces such as Open Graded Asphaltic Concretes.

Table IV Passby noise levels for cars at 80 km/h and 7.5 m determined in the 2003 investigation with the pavement surface macrotextures.

Location	Site	Pavement surface type	Car passby noise level (dB(A))	Pavement surface macrotexture depth (mm)
Abbott Street	SMAC 5	Novachip	72.4	1.57
	SMAC 6	Hushphalt	73.2	1.44
	SMAC 7	LoNoise	71.1	0.80
	DGAC 8	DGAC	75.4	0.61
Boundary Street	SMAC 8	LoNoise	74.3	0.86

Nevertheless, for SMACs 8,6 and 5 there is a clear trend in Figure 2 for the car passby noise levels to reduce with increasing macrotexture, in a similar manner to the behaviour reported in Samuels (2004 A). Again this observation is consistent with the theory mentioned above that greater macrotexture in these types of pavement surface results in more voids being present in the surface structure. Reiterating, this suggests that there is greater apparent porosity which itself leads to more noise reduction (Sandberg and Ejsmont 2002).

CONCLUSIONS

On the basis of what appears in the present paper the following conclusions have been drawn.

- The SPBIs on the DGAC pavement surface in Abbott Street have remained essentially constant over the time period between August 2002 and December 2004.

- The SMAC pavement surfaces in Abbott Street produced the lowest noise levels in December 2004, with the performance of the LoNoise and the Hushphalt now being equivalent and marginally quieter than the Novachip. Both the LoNoise and the Hushphalt pavement surfaces delivered noise reductions of around 3.2 dB(A) over the DGAC in December 2004 and such reductions are both useful and readily noticeable.

- In Abbott Street the acoustic performance of the Novachip improved by a slight 1.4 dB(A) from August 2002 to December 2003, while that of the LoNoise reduced by 1.5 dB(A) over the same period. Overall, the acoustic performances of the Novachip and the LoNoise pavement surfaces in Abbott Street remained stable over the year from December 2003 to December 2004. However the performance of the Hushphalt improved by 1.5 dB(A) over this same year so that the acoustic performance of this pavement surface is now a slight 0.8 dB(A) better than it was in August 2002.

- In Boundary Street the LoNoise pavement surface produced noise levels that were a negligible 0.5 dB(A) lower than the (Abbott Street)DGAC in December 2004 and this was also the case in December 2003. The acoustic performance of this particular LoNoise pavement surface deteriorated by around 3 dB(A) from August 2002 to December 2003 but has remained stable from December 2003 to December 2004.

- Along the Bruce Highway both the Boral and Pioneer SMA 14 pavement surfaces produced essentially the same noise levels in December 2004. The acoustic attributes of both these pavement surfaces were also essentially the same as the (Abbott Street) DGAC which means that in December 2004 neither pavement surface was delivering noise reductions compared to the DGAC. Moreover the acoustic attributes of these two SMACs had remained essentially stable from December 2003 to December 2004.

- The Chip Seal pavement surface on the Bruce Highway produced the highest noise levels of all the pavement surfaces in December 2003 and December 2004, as expected. The acoustic attributes of this Chip Seal pavement surface were comparable to those from other Chip Seals in South-East Queensland and remained stable over the year from December 2003 to December 2004.

- The car passby noise levels on a set of the SMAC pavement surfaces were found to reduce with increasing macrotexture. It was concluded that this occurred because there is greater macrotexture in these types of pavement surface which results in more voids being present in the surface structure. This greater degree of porosity apparently leads to more noise reduction.

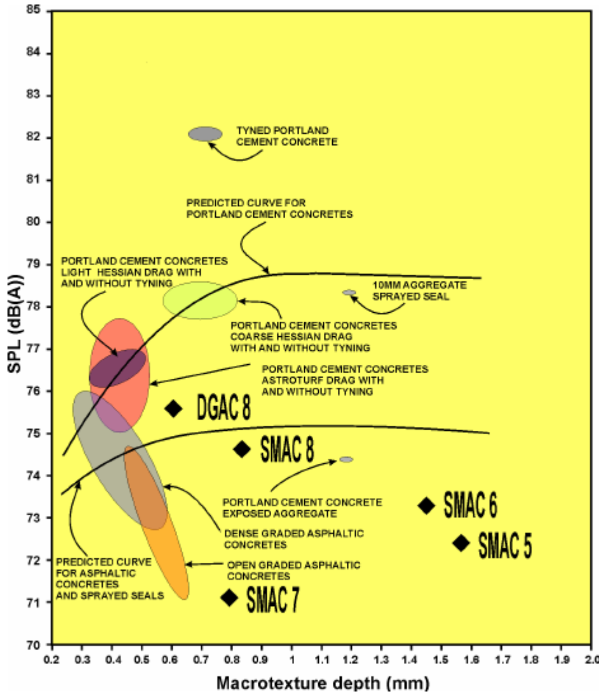

Figure 2. Car passby noise levels at 80 km/h and 7.5 m determined in the 2003 investigation in Townsville overlaid on a plot of pavement surface noise data collected elsewhere in Australia (Samuels 1996).

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