The Long Term Road Traffic Noise Attributes of Pavement Surfaces in Queensland

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ABSTRACT

This paper presents a substantial investigation of the road traffic noise attributes of five types of pavement surface currently in service in Queensland. The investigation was configured to examine the acoustic performance of the set of pavement surfaces and how these performances varied over time. To do this, a considerable set of roadside noise data, measured according to the statistical passby technique, was collected at 29 sites in 2002, 2003 and 2005. These data were collected at 21 sites in South East Queensland and at 8 sites in North Queensland in the Townsville environs. 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 and to exploring how they varied over time. The paper presents and discusses the acoustical attributes of the five types of pavement surfaces studied. It then goes on to set out and consider how the acoustical attributes of the pavement surface types varied over time. Some of the pavement surfaces exhibited very stable acoustical performance over the 2002 to 2005 period while the acoustical performance of others varied somewhat.

INTRODUCTION

The present paper deals with an ongoing investigation of the acoustic attributes of several pavement surfaces in Queensland. It builds on the work reported in Samuels (2004) and in Samuels and Hall (2005 a & b) concerning similar investigations conducted on pavement surfaces in Queensland. Specific objectives of the work reported in the present paper were to determine the noise attributes of the various pavement surfaces and to ascertain if and how the acoustic performance of these pavement surfaces varied over time. Thus the paper brings together the outcomes of a series of investigations that were undertaken in 2002, 2003 and 2005.

As with Samuels (2004) and Samuels and Hall (2005 a & b), the work reported in this paper was conducted within an 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 2002, 2003 and 2005 investigations all shared a common experimental design which involved collecting samples of passby noise data from three vehicle types (cars, medium trucks and heavy trucks) on the pavement surfaces included in the investigations. These noise 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). Roadside measurement locations were set up for this purpose at each of the 29 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 29 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.

The range of pavement surfaces included in the investigations is set out Table 1 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.

OGAC: Open Graded Asphaltic Concrete

SMAC: Stone Mastic Asphaltic Concrete

DGAC: Dense Graded Asphaltic Concrete

CS: Chip Seal (10mm)

PCC: Portland Cement Concrete

Table 1. Pavement surfaces included in the investigations

Pavement Surface Type	Number of sites included in the investigations	
	South East Queensland	Townsville
OGAC	7	0
SMAC	3	6
DGAC	5	1
PCC	3	0
CS	3	1
Total	21	8

Data analysis

All of the statistical passby data were collated and analysed in accord with the established, scientifically based procedures adopted in Samuels and Hall (2005 a & b). 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) and in Samuels and Parnell (2001 and 2003) and will not be repeated here. However, what should be noted here is that comparisons of the SPBIs associated with different pavement surfaces show the variations in traffic noise levels that would occur on these pavement surfaces. The SPBI is defined below in Equation 1 (ISO 1997).

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

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. The SPBI includes the influence of traffic composition through the parameters W_1, W_{2a} and W_{2b}. Specification of the values of these three parameters 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 (subsequently designated 90-05-05).

THE PAVEMENT SURFACE EFFECTS ON TRAFFIC NOISE OVER TIME

The Statistical Passby Indices

The 2002, 2003 and 2005 SPBI data are presented in Tables 2 and 3 and in Figure 1. Note firstly in Table 2 that the standard deviations of the three sets of SPBI data are very consistent with one another, thus reflecting the high quality of the passby noise data collected in all three investigations. Overall it is apparent that there have been only small variations in the SPBIs over the 2002-2003-2005 periods. There have been slight changes in the relativities of the PCCs and CSs over the three sets of investigations. Nevertheless, the trends in the 2005 data are essentially the same as those of the 2003 and 2002 data. The PCCs tended to be the loudest pavement surfaces studied while the OGACs were consistently the quietest. On average the total range from the PCCs to the OGACs was 5.1 dB in 2005 (Table 3) and this range was a little less than in 2003 but a little greater than in 2002.

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

The differences between the SPBIs from the three investigations were explored further in Table 4 where it is apparent that small changes in traffic noise levels would have occurred on the five pavement surfaces over the 2002-2003-2005 periods. The trends apparent in Table 4 are discussed below and are based on the premise that the "high speed" 90-05-05 traffic conditions remained constant throughout the 2002-2003-2005 periods.

- On the OGACs, traffic noise levels would have remained essentially stable from 2002 to 2003 and then increased slightly from 2003 to 2005. In 2005 the traffic noise levels on the OGACs would have been a small 1.3 dB(A) higher than in 2002.
- On the SMACs, traffic noise levels would have very slightly increased from 2002 to 2003 and subsequently increased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the SMACs would have been a small 1.2 dB(A) higher than in 2002.
- Traffic noise levels on the DGACs would have remained very stable over the 2002-2003-2005 periods.
- On the CSs, traffic noise levels would have slightly decreased from 2002 to 2003 and subsequently decreased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the CSs would have been a small 1.8 dB(A) lower than in 2002.
- On the PCCs, traffic noise levels would have slightly increased from 2002 to 2003 and subsequently increased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the PCCs would have been a small 1.7 dB(A) higher than in 2002.

"Within type" variability in pavement surface noise data occurs for any type of pavement surface for which data are collected at several sites (Samuels and Hall 2005 b). Put simply, this means that the noise produced by a given pavement surface at one site will not always be exactly the same as that measured on the same surface at another site.

Table 2. The SPBIs from the 2002, 2003 and 2005 investigations

Pavement Surface Type	Average (and Standard Deviation) SPBI (dB)		
	2005 data	**2003 data**	**2002 data**
OGAC	80.4 (1.4)	78.9 (1.1)	79.1 (1.5)
SMAC	80.6 (1.5)	80.1 (1.2)	79.4 (1.4)
DGAC	80.9 (1.4)	81.1 (1.2)	80.8 (1.8)
CS	83.2 (1.3)	83.9 (0.8)	85.0 (0.8)
PCC	85.5 (1.9)	85.0 (1.3)	83.8 (0.6)

Table 4. Changes in SPBIs over time

Pavement Surface Type	Average SPBI (2003) –Average SPBI (2002) (dB)	Average SPBI (2005) –Average SPBI (2003) (dB)	Average SPBI (2005) –Average SPBI (2002) (dB)
OGAC	- 0.2	1.5	1.3
SMAC	0.7	0.5	1.2
DGAC	0.3	- 0.2	0.1
CS	- 1.1	- 0.7	- 1.8
PCC	1.2	0.5	1.7

In pursuing this issue a little further, the "within pavement surface type" variabilities in the 2005, 2003 and 2002 data were determined and appear in Table 5. These variabilities are, in fact, the standard deviations associated with the average SPBIs in Table 2. It is quite apparent that the "within type" variabilities of Table 5 were all very small over the five pavement surface types of the 2005, 2003 and 2002 data and this observation is in accord with expectation (Samuels and Parnell 2001 & 2003). Overall, the average "within type" variabilities of 1.5, 1.1 and 1.2 for the three data sets shown in Table 5 are very consistent with one another. What has now become apparent is that the magnitudes of these "within pavement surface type" variabilities are comparable to the magnitudes of the SPBI differences over time in Table 4. This is a rather important observation which assists in explaining the fluctuations evident in the data of Figure 1 and in Tables 2, 3 and 4 as discussed previously above.

Table 5. "Within pavement surface" variabililties in the SPBIs

Pavement Surface Type	Magnitude of SPBI Variability (dB)		
	2005 Data	2003 Data	2002 Data
OGAC	1.4	1.1	1.5
SMAC	1.5	1.2	1.4
DGAC	1.4	1.2	1.8
CS	1.3	0.8	0.8
PCC	1.9	1.3	0.6
Mean	1.5	1.1	1.2
Standard Deviation	0.2	0.2	0.5

COMPARISON OF THE ACOUSTIC PERFORMANCE OF SOME OF THE SOUTH EAST QUEENSLAND AND THE TOWNSVILLE PAVEMENT SURFACES

The question is sometimes raised as to whether there are any differences between the acoustic performance of the pavement surfaces in South East Queensland and those in Townsville. To address this question the SPBI data from both areas were examined. SPBI values from the 2005 data set were aggregated into sub populations by pavement surface type and by location and the means and standard deviations of these sub populations determined. The results appear below in Table 6 and overleaf in Figure 2. Note that this analysis was confined to just the SMAC, DGAC and CS pavement surfaces since there were no OGACs or PCCs studied in Townsville (refer to Table I). As shown in Table 6 the sample sizes of the sub populations were all rather small, especially with only one DGAC and one CS in Townsville. Therefore statistical analyses of the data in Table 6 were not possible.

Table 6. Comparison of the 2005 SPBIs from South East Queensland and Townsville.

Pavement Surface Type	Location	SPBI (dB) & Sample Size (-)		
		Mean	Standard Deviation	Sample Size
SMAC	**SE Qld**	79.9	1.5	3
	Townsville	81.0	1.5	6
DGAC	**SE Qld**	80.7	1.5	5
	Townsville	81.7	0	1
CS	**SE Qld**	82.6	0.9	3
	Townsville	84.8	0	1

It appears initially in Table 6 that the Townsville SPBIs are, on average, all slightly higher than their South East Queensland counterparts. These Townsville SPBIs exceed the corresponding South East Queensland SPBIs by small differences (in the means) of 1.1 dB for the SMACs, 1.0 for the DGACs and 2.2 for the CSs. However when interpreting this observation, both the standard deviations and the extremely small sample sizes of the six 2005 sub populations, particularly the Townsville DGAC and CS sub populations, must also be considered. Moreover, the differences apparent in Table 6 are consistent with the within pavement surface type variabilities of Table 5. Taking all these factors into account leads to the conclusion that the 2005 data of Table 6 do not suggest that there were any differences between the acoustic performance of the SMAC, of the DGAC and of the CS pavement surfaces in South East Queensland and in Townsville in that year. However this conclusion must be regarded as tentative, because of the small DGAC and CS sample sizes in Townsville.

Subsequently this comparison was repeated using all the SPBI data pooled from the 2002, 2003 and 2005 investigations. The ensuing results were very similar to those above. Again the means of the Townsville SPBIs appeared to be very slightly higher than their South East Queensland counterparts. Here the differences corresponding to those above were even smaller at 0.3 dB for the SMACs, 1.2 dB for the DGACs and 0.2 dB for the CSs. All of the comments in the paragraph above apply to these results. Consequently it was

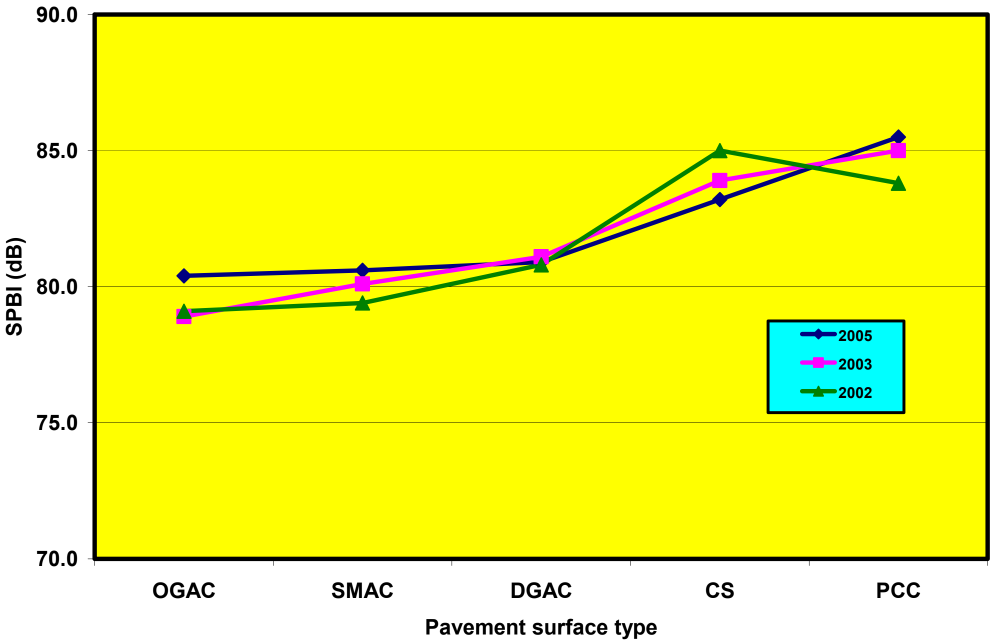

Figure 1. Average SPBIs from the 2002, 2003 and 2005 investigations.

also concluded on the basis of the comparisons of the pooled data that there were no differences between the acoustic performance of the SMAC, of the DGAC and of the CS pavement surfaces in South East Queensland and in Townsville over the 2002-2003-2005 periods.

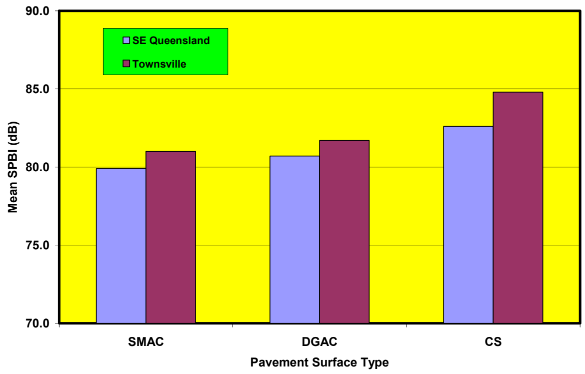

Figure 2. Comparison of mean SPBIs from South East Queensland and Townsville for the 2005 data

CONCLUSIONS

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

- On average the total range in traffic noise levels from the quietest (OGACs) to the loudest (PCCs) pavement surfaces was 5.1 dB in 2005 (Table III) and this range was a little less than in 2003 but a little greater than in 2002.
- It was concluded that some small changes in traffic noise levels would have occurred over the 2002-2003-2005 periods as follows.
  1. On the OGACs, traffic noise levels would have remained essentially stable from 2002 to 2003 and then increased slightly from 2003 to 2005. In 2005 the traffic noise levels on the OGACs would have been, on average, a small 1.3 dB(A) higher than in 2002.
  2. On the SMACs, traffic noise levels would have been very slightly increased from 2002 to 2003 and subsequently increased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the SMACs would have been, on average, a small 1.2 dB(A) higher than in 2002.
  3. Traffic noise levels on the DGACs would have remained very stable over the 2002-2003-2005 periods.
  4. On the CSs, traffic noise levels would have slightly decreased from 2002 to 2003 and subsequently decreased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the CSs would have been, on average, a small 1.8 dB(A) lower than in 2002.
  5. On the PCCs, traffic noise levels would have slightly increased from 2002 to 2003 and subsequently increased very slightly more from 2003 to 2005. In 2005 the traffic noise levels on the PCCs would have been, on average, a small 1.7 dB(A) higher than in 2002.
  6. In summary it was concluded that over the 2002-2003-2005 periods there had been some small variations in the acoustical attributes of the pavement surfaces studied. These variations are set out above and in Table 4. Overall, the magnitudes of these variations from 2002 to 2005 ranged from 0.1 to 1.8 dB.
- It was also observed in all three investigations that there were small within type variabilities present in the data over the five pavement surface types and this observation was in accord with expectation. The average within type variabilities were 1.5 dB for the 2005 data, 1.1 dB for the 2003 data and 1.2 dB for the 2002 data (refer to Table 5). These figures were regarded as being rather small and as being very consistent with one another. In fact the magnitudes of these within pavement surface type variabilities were comparable to the magnitudes of the small differences in the traffic noise levels that would have occurred on the five pavement surface types over the 2002-2003-2005 periods and which are summarised immediately above.
- A limited investigation was undertaken to determine if there were any differences between the acoustic attributes of the pavement surfaces studied in South East Queensland and those studied in the Townsville environs. This investigation was confined to just the SMAC, DGAC and CS pavement surfaces since there were no OGACs or PCCs studied in Townsville. It was concluded that there were no differences between the acoustic attributes of the SMAC, of the DGAC and of the CS pavement surfaces in South East Queensland and in Townsville in 2005 or over the 2002-2003-2005 periods. However these conclusions must be regarded as tentative, because of the small DGAC and CS sample sizes in Townsville.

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