The Queensland Department of Main Roads Pavement Surface Noise Resource Manual

Arthur Hall (1)* , Stephen Samuels (2)

(1) Planning Design and Environment Division, Queensland Department of Main Roads, Brisbane, Australia
(2) TEF Consulting and Visitng Research Fellow, University New South Wales, Sydney, Australia

ABSTRACT

Since road pavement surface type is such an important factor in the generation of traffic noise, much research has been conducted in Australia and internationally on this topic. Over the last several years, the Authors have collaborated on a series of investigations for the Queensland Department of Main Roads (QDMR), which have been directed at determining the acoustic attributes of various Queensland pavement surface types. Some of these investigations have been presented at recent AAS Annual Conferences. The conduct and outcomes of these investigations, along with their applications, have been brought together in a document known as the QDMR Pavement Surface Noise Resource Manual (PSNRM). Throughout the investigations, collection of the required pavement surface noise data was undertaken according to the statistical passby technique. In total, 33 Sites of varying pavement surfaces were included in the investigations and of these 24 were in South East Queensland and 9 were in the Townsville environs. These data have been analysed to determine the values of the Statistical Passby Index for the each of the pavement surfaces. The Statistical Passby Index may be used to quantify the overall effects of pavement surface type on traffic noise. Thus the paper introduces the QDMR Pavement Surface Noise Resource Manual, presents some of its key contents and explains some of its applications.

INTRODUCTION

Since road pavement surface type is such an important factor in the generation of traffic noise, much research has been conducted in Australia and internationally on this topic (Samuels 1982, Samuels and Dash 1996, Samuels and Parnell 2002, Sandberg and Ejsmont 2002). The acoustic performances of various pavement surface types have been scientifically investigated in Queensland and are set out in great detail in the QDMR Pavement Surface Noise Resource Manual (Samuels 2005). This Manual primarily focuses on the following pavement surface types, which are widely used throughout Queensland and indeed throughout Australia and internationally.

A Chip Seal (CS) is a thin pavement comprising a layer of bitumen onto which crushed rock has been placed and compacted by a rolling process.

A Portland Cement Concrete (PCC) is a reinforced cement concrete pavement that may have various surface textures applied by tyning and similar processes.

An Asphaltic Concrete (AC) is comprised of fine, uniform crushed rock in a bituminous binder and is commonly applied on arterial roads and residential streets throughout Australia. The so-called **Dense Graded Asphaltic Concrete (DGAC)** is a smooth, uniform pavement that typically varies in depth from around 25mm to 250mm, depending on the traffic loading conditions.

A Stone Mastic Asphaltic Concrete (SMAC) is a type of DGAC that has additives, such as rubber, in the binder and also incorporates crushed rock of varying sizes.

An Open Graded Asphaltic Concrete (OGAC) is comprised of a porous layer, usually a minimum of 25 to 30 mm thick, which is usually overlaid on a DGAC and which provides a water drainage path within the porous layer. This type of pavement surface has also been referred to as an **Open Graded Friction Course**.

What appears in the present paper has ensued from a series of investigations undertaken by the authors for the Queensland Department of Main Roads (QDMR) which have been directed at investigating various aspects of the acoustic attributes of pavement surfaces in Queensland.

THE ACOUSTIC ATTRIBUTES OF QUEENSLAND PAVEMENT SURFACES

Determination of the acoustic attributes

In the investigations mentioned above, collection of the required pavement surface noise data was undertaken according to what is known as the statistical passby technique (ISO 1997), as also explained in Samuels and Hall (2005) and in Samuels (2004). In total, 33 Sites of varying pavement surface types were included in the investigations and of these 24 were in South East Queensland and 9 were in the Townsville environs. At each of these 33 sites, statistical passby data were collected for around 100 cars, 20 medium trucks and 20 heavy trucks. These data have been analysed to determine the values of the Statistical Passby Index for the each of the pavement surfaces, again as explained in Samuels and Hall (2005) and in Samuels (2004). The SPBI is defined below in Equation 1 (ISO 1997).

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

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, which are designated by the subscripts 1, 2a and 2b in Equation 1, are Cars (1), Medium Trucks (2a) and Heavy Trucks (2b). The SPBI may be calculated for three speed conditions, known as "high", "medium" and "low". Within each of these conditions vehicles are assigned the following Reference Speeds.

"High": Cars 110km/h and trucks 85km/h

"Medium" Cars 80km/h and trucks 70km/h

"Low": Cars 50km/h and trucks 50km/h

In order to calculate the SPBI for a particular pavement surface according to Equation 1, it is necessary firstly to determine the values of L_1, L_{2a} and L_{2b} for the pavement surface. This has been done as part of the pavement surface noise investigations which have been mentioned above. 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. A set of 8 traffic compositions which are listed below in Table I has been used for this purpose. These compositions cover a suitably wide range from the situation of traffic comprising cars only, to that comprising 10% medium trucks in addition to 40% heavy trucks. Thus SPBIs have been determined for each of these 8 traffic compositions, at the "high", "medium" and "low" speed conditions for every one of the 33 pavement surfaces mentioned above. By analysing these SPBIs and aggregating them by pavement surface type, the relative acoustic attributes of the pavement surface types has been obtained.

Table I. Traffic conditions adopted for the SPBI calculations

Traffic condition identifier	Traffic composition (%)		
	Cars	Medium trucks	Heavy trucks
100 – 0 – 0	100	0	0
95 – 0 – 5	95	0	5
95 – 2.5 – 2.5	95	2.5	2.5
90 – 5 – 5	90	5	5
80 – 5 – 15	80	5	15
70 – 10 – 20	70	10	20
60 – 10 – 30	60	10	30
50 – 10 - 40	50	10	40

The relative acoustic performance of the Queensland pavement surfaces

The Statistical Passby Indices are presented in the PSNRM for the "high", "medium" and "low" speed conditions and for just four traffic conditions. Samuels and Parnell (2002) demonstrated that it was only necessary to utilise three or four traffic compositions to demonstrate the effects of traffic composition on the SPBIs. For the present paper, just the "high" speed SPBIs appear in Figure 1 and Table II.

Table II. The Statistical Passby Indices over four traffic conditions at high speed

Pavement Surface Type	Average (and Standard Deviation) SPBI (dB)			
	Traffic: 50-10-40	Traffic: 70-10-20	Traffic: 90-5-5	Traffic: 100-0-0
OGAC	81.7 (1.3)	80.4 (1.2)	78.9 (1.1)	78.1 (1.0)
SMAC	84.0 (1.3)	82.3 (1.2)	80.1 (1.2)	78.7 (1.3)
DGAC	84.7 (1.5)	83.1 (1.4)	81.1 (1.2)	80.0 (1.2)
10mm CS	85.8 (0.7)	84.9 (0.7)	83.9 (0.8)	83.4 (1.0)
PCC	88.1 (1.0)	86.7 (1.1)	85.0 (1.3)	84.2 (1.5)
OGAC - DGAC	-3.0	-2.7	-2.2	-1.9
SMAC – DGAC	-0.6	-0.8	-1.0	-1.3
DGAC – DGAC	0.0	0.0	0.0	0.0
CS – DGAC	1.2	1.8	2.8	3.4
PCC - DGAC	3.4	3.6	3.9	4.2
PCC – OGAC	**6.4**	**6.3**	**6.1**	**6.1**

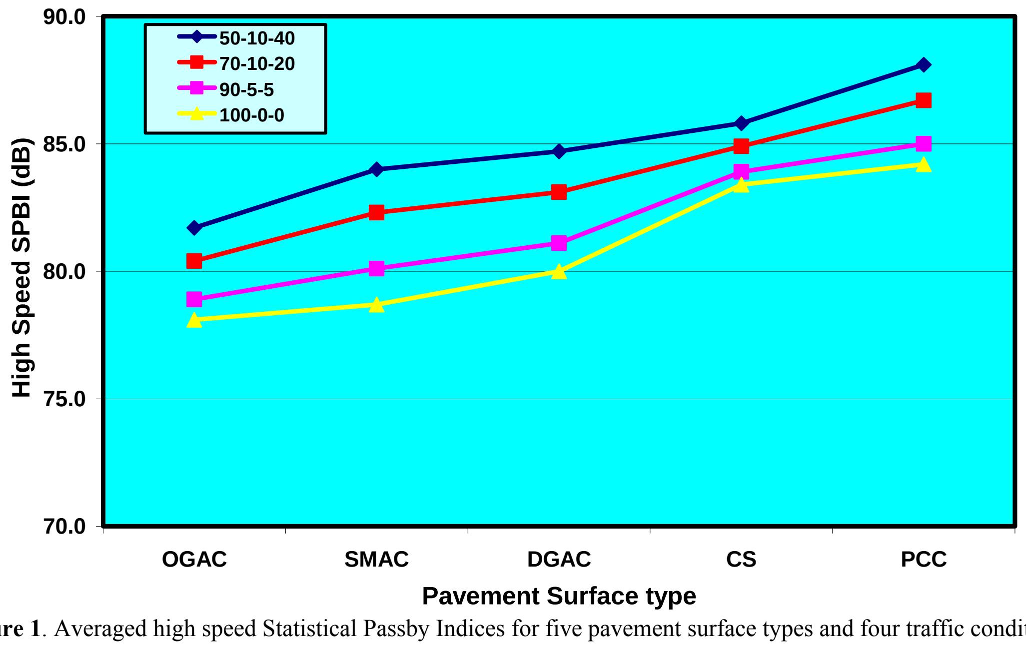

Figure 1. Averaged high speed Statistical Passby Indices for five pavement surface types and four traffic conditions.

Note that the SPBIs in Figure 1 are the average values for each pavement surface type. The associated standard deviations were, as exemplified in Table II, all very low and ranged from 0.7 to 1.5 dB over all traffic composition and speed conditions. The SPBI data in Figure 1 and Table II indicate that traffic noise levels vary considerably with pavement surface type. Relative to DGAC, and irrespective of the traffic speed conditions, traffic noise will be 1.9 to 3.0 dB(A) quieter on an OGAC and 3.4 to 4.2 dB(A) louder on a PCC pavement surface, depending on the traffic composition. Similarly, the overall range of traffic noise levels from a PCC to an OGAC pavement surface is 6.1 to 6.4 dB(A).

The effects of pavement surface type on traffic noise

Further detailed discussions and interpretations of the data tabulated and graphed above appear in the PSNRM (Samuels 2005). In order to apply the SPBIs to quantifying the effect of pavement surface type on traffic noise, it was necessary firstly to determine the means and standard deviations of the data in the bottom part of Table II and the results of this process are presented in Table III, along with the corresponding results for the other two traffic speed conditions. To interpret what appears in Table III, consider the example of the change in SPBI from an OGAC to a DGAC for high speed traffic conditions which has a mean value of 2.5 dB with an associated standard deviation of 0.5

dB. These two figures were obtained from a simple statistical analysis of the four figures in the OGAC-DGAC row in the bottom part of Table II. In other words, over the range of traffic compositions from 50-10-40 to 100-0-0, on average the increase in SPBI from an OGAC to a DGAC under high speed traffic conditions was 2.5 dB (with an associated standard deviation of 0.5 dB).

Table III. Effects of the five Queensland pavement surface types on the SPBIs

Pavement surface type compared	**Change in SPBI (dB)**					
	High Speed Traffic		**Medium Speed Traffic**		**Low Speed Traffic**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
OGAC – DGAC	-2.5	0.5	-2.5	0.5	-2.6	0.5
SMAC-DGAC	-0.9	0.3	-0.9	0.3	-1.0	0.6
DGAC – DGAC	0.0	0.0	0.0	0.0	0.0	0.0
CS – DGAC	2.3	1.0	2.1	1.1	2.0	1.2
PCC – DGAC	3.8	0.4	3.7	0.4	3.7	0.4
PCC - OGAC	**6.2**	**0.1**	**6.3**	**0.1**	**6.2**	**0.2**

Returning to Table III it is apparent that the changes in SPBI for the high speed traffic conditions are essentially the same as those for the other two traffic conditions. There are some very small differences, but these may be neglected as artefacts of the way in which Excel rounded all the data in Table III. Consequently it was concluded that, irrespective of the traffic speed conditions, the overall change in SPBI from the loudest (PCC) pavement surface to the quietest (OGAC) was 6.2 dB. Furthermore, the SPBIs for the PCCs were 3.8 dB higher than the SPBIs for the DGACs with the OGAC SPBIs being 2.5 dB lower than those of the DGACs. This means that for high, medium and low speed traffic over traffic compositions from 100-0-0 to 50-10-40, the effects of pavement surface type on traffic noise levels alongside Queensland roads are as set out in detail in Table IV.

Table IV. Overall effects of Queensland pavement surface types on traffic noise

Change in pavement surface type	**Average change in traffic noise level (dB(A))**
DGAC to OGAC	- 2.5
DGAC to SMAC	- 0.9
DGAC datum	0.0
DGAC to CS	+ 2.3
DGAC to PCC	+ 3.8
OGAC to PCC	**+ 6.2**

OTHER CONSIDERATIONS CONCERNING THE EFFECTS OF QUEENSLAND PAVEMENT SURFACE TYPES ON TRAFFIC NOISE

The long term acoustic attributes of Queensland pavement surfaces

Data had been collected repeatedly on the five pavement surface types listed above in South East Queensland and in the Townsville environs on a number of occasions from December 2000 to December 2003, over intervening periods from 6 to 33 months. Analyses of these data were applied to an investigation of the long term acoustic attributes of the five pavement surface types and the outcomes are documented in the PSNRM. It was observed that there were small differences between the SPBIs of the five pavement surface types over the various intervening times between the earlier and latest studies. The magnitudes of these differences ranged from 0.2 to 1.2 dB. Consequently it was concluded that the small changes in the SPBIs of each pavement surface over time may reasonably be regarded as negligible. In other words the acoustic attributes of the five pavement surfaces (over intervening periods from 6 to 33 months) have remained essentially stable for each pavement surface type.

An additional follow up study of the long term acoustic attributes of the 8 pavement surfaces in Townsville was undertaken in December 2004. Overall, it was found that while some small changes had occurred between August 2002 and December 2003, in the subsequent year to December 2004 the acoustic attributes of the Townsville pavement surfaces had remained essentially stable. Refer to Samuels (2004) and to Samuels and Hall (2005) for further details.

The acoustic attributes of the South East Queensland pavement surfaces compared to those in the Townsville environs

A limited investigation presented in the PSNRM was conducted to determine if there were any differences between the acoustic attributes of the pavement surfaces tested in South East Queensland and those tested 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 pavement surfaces in South East Queensland and those in Townsville. The same conclusion was tentatively made for the CSs, even though there was only one sample from Townsville. On the other hand, it was very cautiously concluded, because of the small sample size in Townsville, that the traffic noise on the Townsville DGACs would be around 2 dB(A) louder than that on the South East Queensland DGACs.

The effect of pavement surface cleaning on the acoustic attributes of an OGAC pavement surface

Another limited investigation was conducted on the effect of pavement surface cleaning on the acoustic attributes of an OGAC pavement surface in South East Queensland and again this is documented in the PSNRM. The conclusion of this investigation was that the pavement surface cleaning treatment had a negligible effect on the noise attributes of the OGAC pavement surface. An alternative expression of this particular conclusion was that the cleaning treatment was found to have no adverse effects on the low noise properties of the OGAC pavement surface tested. In noting this conclusion, it must be recognised that no information was available to the investigation of the pavement surface properties such as permeability before and after the pavement surface cleaning process was conducted.

CONCLUSIONS

The QDMR Pavement Surface Noise Resource Manual is a substantial document which is based on a series of research and development projects undertaken by the Authors over a number of years. It sets out the acoustic attributes of pavement surfaces adopted throughout Queensland and provides some practical applications of these attributes in the prediction, assessment and control of road traffic noise.

REFERENCES

International Standards Organisation (1997). ISO 11819-1, Acoustics – Methods for measuring the influence of road surfaces on traffic noise. Part 1 – the statistical passby method. ISO, Geneva, Switzerland.

Samuels, S.E. (1982). The generation of tyre/road noise. Australian Road Research Board. Research Report, ARR No. 121. ARRB Transport Research, Vermont South, Victoria.

Samuels, S.E. (2004). The long term road traffic noise attributes of some pavement surfaces in Townsville. Proc. Annual Conf. Australian Acoustical Society, Gold Coast, Queensland. pp549 – 553. Australian Acoustical Society, Brisbane, Queensland, Australia.

Samuels, S.E. (2005). The QDMR Pavement Surface Noise Resource Manual. TEF Consulting Draft Report 4040 to QDMR Planning, Design and Environment Division, March 2005. TEF Consulting, Cronulla, NSW.

Samuels, S.E. and Dash, D. (1996). Development of low noise pavement surfaces in Australia. Proc PIARC Road Surfacing Symposium, Christchurch, New Zealand.

Samuels, S.E. and Hall, A.M. (2005). A further study of the long term acoustic attributes of some pavement surfaces in Townsville. Submitted for publication in proceedings of the Australian Acoustical Society Annual Conference, Busselton, Western Australia. Australian Acoustical Society, Perth, Western Australia.

Sandberg, U. and Ejsmont, J.A. (2002). Tyre/road noise reference book. Informex, Kisa, Sweden.

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