Effects of Road Surface Texture on Traffic and Vehicle Noise

GEORGE GLAZIER AND STEPHEN SAMUELS

Seven different pavement types, ranging from asphaltic concrete, open-graded and dense-graded, to cement concrete, with various surface textures, were required to be tested to obtain the relative noise from the interaction of tires on those pavements. Three methods were chosen, and these are discussed, together with an assessment of their respective merits and the overall results.

This study, conducted by the Australian Road Research Board (ARRB), grew out of a previous recommendation of one of the authors "that the use of 'quieter' pavement surfaces such as open graded asphaltic concrete (OGAC) be adopted through residential or other noise sensitive areas, in lieu of concrete (grooved, brushed, or smooth)—on new constructions."

The original intention of that recommendation was to involve testing of two, three, or at most four surface types by a comparative method in which two of the surface types could be found in suitable adjoining locations. These were to be OGAC, dense-graded asphaltic concrete (DGAC), and a few of the portland cement concrete (PCC) pavements (e.g., deep grooved, shallow grooved, hessian dragged, etc.).

Subsequently, the New South Wales Roads and Traffic Authority (RTA) decided to expand the study to cover a total of 10 pavement types, including examples of a cold overlay slurry seal, a 14-mm chip seal, and two examples of polymer-bound OGACs and normal OGACs to two different specifications (1975 and 1987).

TEST METHODS

Traffic Noise

At each site, four 15-min samples of traffic noise were collected using Bruel and Kjaer Type 4426 noise analyzers. These samples provided the conventional indices L10, L50, L90, and Leq as well as histograms of the traffic noise level distributions. At some sites, the L1 index was also monitored. During two of the four samples, tape recordings of the traffic noise were also made. Traffic volumes, composition, and speeds were monitored during all sample periods by means of the ARRB-developed video analysis data acquisition system. It comprises a video camera mounted atop a vertical mast attached to a small trailer. After suitably positioning the trailer adjacent to the road, the mast is extended pneumatically up to an optimum viewing height (not exceeding 10 m). Signals from the camera are recorded on a video cassette recorder mounted inside the trailer. On return to the laboratory, the tapes are replayed into an analysis system to determine the required traffic characteristics. Manual checks were also kept to complement these data.

Vehicle Noise

Sets of individual vehicle noise data were also collected at 10 sites. Peak roadside noise levels were measured for individual, isolated vehicles in the traffic as they passed the monitoring station. These data were obtained using a Bruel and Kjaer precision sound level meter (Type 2203). Vehicles were classified as either cars or heavies as per U.K. Department of Environment (1975) and the carriageway in which they were traveling was also noted. The passby speed of each vehicle was measured by means of a radar speed gun.

Comparative Noise

In several cases, two sites of differing surface type were within 2 km of one another along the one road. Under these conditions, data were monitored simultaneously at both sites. Such simultaneous monitoring was conducted at the following pairs of sites:

- OGAC (1987) versus DGAC;
- OGAC (1987) versus PCC, shallow-grooved;
- PCC, shallow-grooved versus PCC, hessian-dragged;
- PCC, hessian-dragged versus cold overlay slurry seal; and
- DGAC versus PCC, deep-grooved.

General

All data were collected in accordance with the provisions of Australian Standard 2702 under still dry condition—the latter despite an unusually wet period in and around Sydney.

Further, the physical dimensions of each site were recorded, including the distance of the microphone from the center of the nearest travel lane—generally 4 to 7 m.

RESULTS

Traffic Noise

L10 (1-hr) levels were predicted for each site and for each sampling period within each site, by the U.K. Department of

Wilkinson Murray Griffiths Pty Ltd., 246A Willoughby Road, Crows Nest, New South Wales 2065, Australia.

Environment (1975) model, using the measured traffic characteristics and site dimensions—each carriageway separately, then combined. The resultant site sound pressure levels (SPLs) were then related to a chosen reference condition to give a correction factor, *b*, for each site and sample period. Overall, this factor varied from −3.0 to +2.1 dB(A), which is a considerable range.

This correction factor, *b*, quantifies the between-site and between-sample variability. By applying it to the measured levels, all variable factors, except the different pavement textures, were eliminated. The resultant L10 (1-hr) levels are presented in Table 1, together with the L10 (1-hr) values related both to the quietest pavement type (open-graded asphaltic concrete, 1987 specification) and the more commonly used (to date) dense-graded asphaltic concrete pavement.

The deep-grooved PCC pavement was clearly the one from which emanated the most noise from traffic. This conforms to the decree of public disapproval expressed. That texture of pavement is unlikely to be used again in a residential area. The shallow-grooved PCC was shown to be the next loudest, of the order of 3.4 dB(A) quieter than the deep-grooved PCC. The third PCC pavement tested was the hessian dragged PCC, which was found to have an advantage of the order of 3 dB(A) over the shallow-grooved PCC.

In regard to the asphaltic concrete pavements, the 1987 specification for OGAC appeared to have an acoustic advantage of the order of 2 dB(A) over the 1975 specification OGAC and of the order of 6 dB(A) over dense-graded AC, with the cold overlay slurry seal performing slightly better than DGAC [of the order of 1 dB(A) better].

Vehicle Noise

At each site, the vehicle noise data set contained the following information for each vehicle:

- Peak passby noise level,
- Vehicle type,
- Vehicle speed, and
- Lane of travel.

The road surface effects were investigated by comparing the vehicle noise levels having due regard for the (between- and within-site) propagation distances and the vehicle speed. The former was achieved by applying the inverse square law, whereas the latter involved the 40 log (speed) relationship. With speed, all data were corrected to 80 km/hr, whereas with distance a reference value of 4.4 m was adopted. The reference distance was the nearside lane propagation distance for one of the dense-graded asphaltic concrete sites. Including the speed corrections, the vehicle noise corrections spanned a range of around 10 dB(A) in total sites. Aggregated, corrected vehicle noise levels are plotted in Figure 1, and show the same trends as the traffic noise data (Figure 2).

TABLE 1 RANKING OF SURFACE TYPES BASED ON TRAFFIC NOISE

Road Surface Type	L10 (1h) dB(A)	∆L10 (1h)	σL10 (1h)
PCC "deep grooved"	87.2	3.8	9.7
PCC, "shallow grooved"	83.8	0.4	6.3
Dense graded asphaltic concrete	83.4	0	5.9
Cold overlay slurry seal	82.6	-0.8	5.1
PCC, "hessian dragged"	80.8	-2.6	3.3
Open graded AC (1975 spec)	79.3	-4.1	1.8
Open graded AC (1987 spec)	77.5	-5.9	0

Table 2 indicates similar trends for the different pavement types (for vehicle noise) to those trends for traffic noise in Table 1, given the variability in both vehicle and traffic noise levels at each site. In Table 2, there are three surface types not included in Table 1. The 14-mm chip seal (CS) and the two polymer-based OGAC pavements were tested only for vehicle noise, as described earlier, and not for total traffic noise. The rankings in Table 2 are given as in Table 1, i.e., related both to the quietest pavement type (OGAC) and to dense GAC, and in the case of Table 2 for both cars and heavy vehicles (those weighing in excess of 1,545 kg).

(Heavy vehicles were not measured in the case of the two polymer-based OGAC pavements because this was in the outside lane only, near the end of a long uphill run, where the noise from heavy vehicles was dominated by engine and exhaust components.)

Comparative Noise Measurements

With pairs of sites on the one road (same traffic, same mix of light and heavy vehicles, and same speeds) separated by up to 2 km, the only variables remain the site dimensions (in some cases) and the textures of two different pavement types.

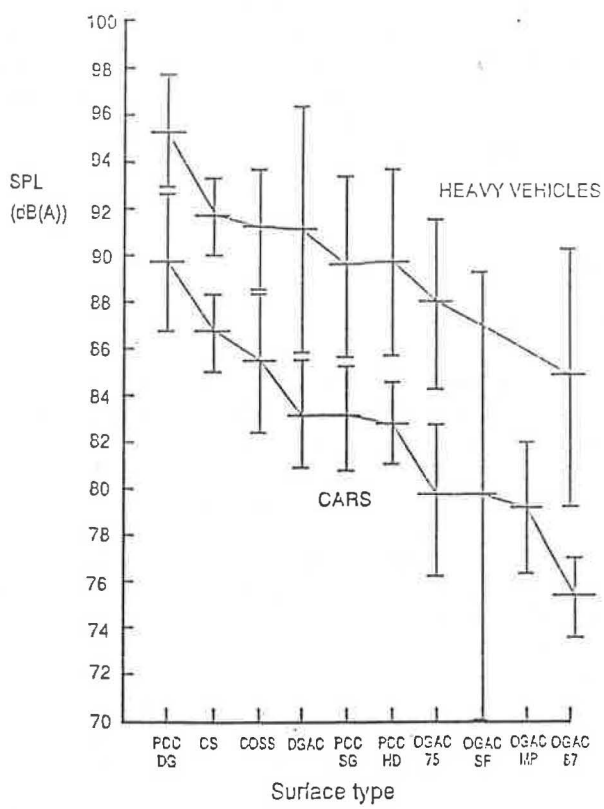

FIGURE 1 Vehicle noise data shown as a mean level plus or minus one standard deviation for each road surface type.

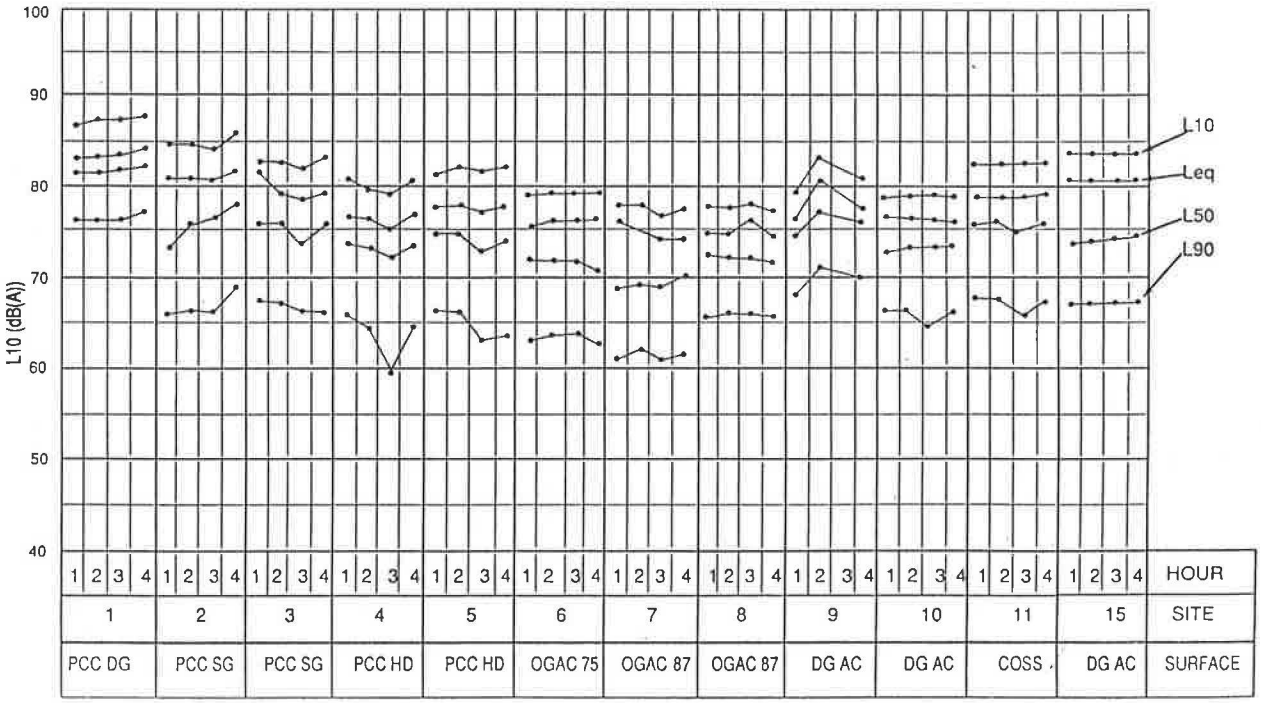

FIGURE 2 Distribution of measured traffic noise levels.

TABLE 2 RANKING OF SURFACE TYPES BASED ON INDIVIDUAL VEHICLE NOISE

Road Surface Type	CARS SPL dB(A)	CARS δ SPL dB(A)	CARS δ SPL dB(A)	HEAVY VEHICLES SPL dB(A)	HEAVY VEHICLES δ SPL dB(A)	HEAVY VEHICLES δ SPL dB(A)
PCC, DG	89.8	6.7	14.4	95.4	4.7	10.7
Chip seal (14mm)	86.7	3.6	11.3	91.7	1.0	7.0
COSS	85.5	2.4	10.1	91.1	0.4	6.4
DGAC	83.1	0	7.7	90.7	0	6.0
PCC, SG	83.0	-0.1	7.6	89.3	-1.4	4.6
PCC, HD	82.8	-0.3	7.4	89.7	-1.0	5.0
OGAC (1975 spec)	79.5	-3.6	4.1	88.1	-2.6	3.4
OGAC - Sealflex	79.5	-3.6	4.1	--	--	--
OGAC - Mobilplas	79.1	-4.0	3.7	--	--	--
OGAC - (1987 spec)	75.4	-7.7	0	84.7	-6.0	0

TABLE 3 RANKING OF SURFACE TYPES BASED ON COMPARING PAIRS OF PAVEMENT TYPES AND TRAFFIC NOISE

Road Surface Type	"Average" L10 (1h) dB(A)	δ L10 (1h) dB(A)	δ L10 (1h) dB(A)
PCC "deep grooved"	87.2	7.4	9.4
PCC, "shallow grooved"	83.6	3.8	5.8
Cold overlay slurry seal	82.6	2.8	4.8
PCC, "hessian dragged"	81.0	1.2	3.2
Dense graded AC	79.8	0	2.0
OGAC (1987 spec)	77.8	-2.0	0

After any necessary corrections for site dimensions were made, two sites at a time were compared—those pairs of sites listed earlier.

Thus, it was expected to be able to produce a ranking of pavement textures from loudest to quietest. However, the first ranking that resulted was vastly different from the previously determined rankings and it was realized that this was obviously caused by differences in textures even between the two OGAC (1987 specification) pavements (for example), and between the two dense GAC pavements, because in each case these were on different roads, as also were the two PCC hessian-dragged pavements, etc.

Knowing this fact, the two pavements of each type were averaged, then the average values were compared, which gave answers similar to those given earlier and in Table 1, except for the dense-graded AC. The resultant rankings based on those average L10 (1-hr) levels are presented in Table 3.

The difference in ranking of the dense-graded AC pavement as presented in Table 1 and in Table 3 is believed to be because one particular site was excluded in the Table 1 preparation but included in the Table 3 preparation. At that site, the traffic was relatively close to an interchange, with some variations in speed of traffic as it entered the freeway or as it slowed to exit.

CONCLUSIONS

On the basis of the results and analyses, the following conclusions may be drawn:

- Road traffic noise levels are affected by road surface treatment. For the surfaces investigated, the total range of L10 (1-hr) levels was almost 10 dB(A).
- Vehicle noise observations supported those of the traffic noise. Road surface treatment had similar effects on both car and heavy-vehicle noise levels.
- By far the loudest surface was the dense-graded PCC. For the remaining surfaces, the noise levels ranged through approximately 6 dB(A).
- The quietest surface was clearly the OGAC 87, which was approximately 3 and 6 dB(A) down on the hessian-dragged and surface-grooved surfaces, respectively.

- Mobilplas- and Sealflex-type polymer-bound OGAC surfaces produce approximately the same vehicle noise levels. In turn, these levels are approximately equivalent to those of the 1975 specification OGAC.
- A 14-mm chip seal could reasonably be expected to generate traffic noise levels in the order of 2 dB(A) higher than a DGAC and 8 dB(A) higher than the 1987 OGAC.

The following observations may be added:

- The tape recordings taken, as back-up for the field measurements, were given to the client. Frequency analyses from those tapes would have been interesting as further comparisons, but were not part of the brief so were not conducted by the consultants. If the tapes are available, even now those frequency analyses could be of interest.
- The PCC pavements have been described as deep grooved, shallow grooved, and hessian dragged. The RTA concrete pavement group have since advised that "grooved" is not an acceptable term, but that two methods of making the grooves have been used—brushing and tyning. Brushing is the drawing of a broom across the wet concrete surface transversely. Some of these, including the test pavement described as PCC, deep-grooved, have much deeper grooves than is actually required for skid resistance purposes. It is understood that this method has now been discontinued. Tyning is the forming of the grooves by drawing a special rake transversely over the wet concrete. This method produced grooves not as deep as by brushing, and more recently grooves even shallower to what is now quite common and is referred to as PCC, shallow-grooved.
- Some of the earlier tyned surfaces produced nonrandom grooves, but generally a random pattern has more recently resulted from this process. The PCC shallow-grooved pavement tested had a random pattern.
- The dates of laying the OGAC, both in the 1975 and 1987 specifications, were not determined and recorded. This is unfortunate, because it may have shown up different results as being caused by degradation of the voids with age. It is suspected particularly that this may have accounted for the difference in levels measured in the two different specifications of OGAC. It is considered that further testing of the degradation of OGAC with age, from an acoustic point of view, is warranted.
- When choosing sites, some OGAC pavements, even some laid down within 2 years, appeared to have texture characteristics almost of a dense-graded AC pavement. This pointed to the need for careful laying to be carried out if the acoustic (and probably other) benefits of OGAC are to be fully realized.
- Concurrently, a separate monitoring program was being carried out on a new section of freeway. Some sections of PCC, shallow-grooved pavement, and adjacent, hessian-dragged PCC pavement were covered with OGAC. Levels taken at houses adjacent to the freeway corridor, in the vicinity of the junction of the two PCC pavement types, before and after the laying of the OGAC (some houses in an elevated topography and others in a situation level with the freeway pavement), indicated an average improvement of 4.5 dB(A) in the L10 (18-hr) levels. This is close to the average value of the 6.3 and 3.3 values for these pavements indicated in Table 1, which tends to confirm the findings therein.

ACKNOWLEDGMENT

This study was conducted by the Australian Road Research Board under contract to the New South Wales Roads and Traffic Authority.

Publication of this paper sponsored by Committee on Transportation-Related Noise and Vibration.