Effect of Pavement Texture on Traffic Noise

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Noise from highway vehicles primarily comes from engine exhausts, tire-pavement interaction, gears, and rattles. Studies have shown that at high speeds tires become the dominant generators of noise. Measurements on different road surfaces have produced different noise-versus-speed relationships (1). This led to the road surface adjustment used in the noise prediction procedure developed in National Cooperative Highway Research Program (NCHRP) Report 117 (2). This adjustment called for a 5-dBA reduction for smooth surfaces (very smooth, seal-coated asphalt pavement) and a 5-dBA increase for rough surfaces [rough asphalt pavement with voids 12.7 mm (0.5 in) or larger in diameter and grooved concrete]. There was no adjustment for normal surfaces (moderately rough asphalt and concrete pavements).

The surface descriptions are vague, and it is left to the discretion of the user to apply adjustments where applicable. We considered using the term "rough" but abandoned it because it seemed vague and possibly misleading. In addition, various degrees of roughness gave a wide range of noise levels. In fact, the terms "smooth," "normal," and "rough" appear to address only that portion of tire noise generated by drumming or percussion of the tire against knobs in the pavement surface. "Smooth" does not distinguish "smooth and dense" from "smooth and porous." It has been argued that an adjustment of -5 dBA should not be used because some truck tires become excessively noisy on very smooth surfaces and because such surfaces are presumed to be ready for renewal because of their inherent low friction characteristics (3). Minimum noise is believed to be associated with smoothness and optimum porosity. In this report, surfaces are identified according to Kentucky specifications.

Noise data were taken on all major types of surfaces currently used in Kentucky. A reference automobile was used to determine any difference in noise. Strip-chart records were made to evaluate the effect type of road surface had on the noise of the entire traffic stream.

PROCEDURE

Noise data were taken on the 8 types of surfaces, which are given in Table 1. All data were taken at locations having zero grade; the observer was level with the roadway and had no shielding. The distance from the center of the lane tested to the noise-level meter was 50 ft (15 m). The locations were selected to give as great a range in traffic exposure as possible. A precision sound-level meter was used for all measurements; measurements were recorded on a strip-chart recorder.

Two reference cars were used for single-vehicle tests. Care was taken to ensure that no error was introduced in using two different cars. Data were taken at 48, 72, and 97 km/h (30, 45, and 60 mph) at each location when possible. The data taken at 72 km/h (45 mph) were used for direct comparisons because 48- and 97-km/h (30- and 60-mph) tests at all locations could not be obtained. The meter readings were noted by the operator as the reference vehicle passed. Measurements were taken only when the noise from the reference cars could be clearly isolated from the traffic stream. Test runs were made at each speed and until representative measurements were obtained. In all cases, the ground cover between the roadway and observer was short grass. Noise levels were also taken inside the cars at 72 km/h (45 mph). A reference truck was used at one location.

To evaluate the effect of type of surface on the noise of the traffic stream, we compared strip-chart records with predicted values. The measured L_{10} noise level (level exceeded 10 percent of the time) was determined from a 10-min chart record. Noise levels on the chart were read at slightly greater than 1-s intervals in the laboratory by using a digitizing data reduction system and computer cards. The L_{10} noise level was computed. The predicted noise level was determined by the method developed in NCHRP Report 117 (2) but then corrected according to the nomograph developed for Kentucky data (4). No adjustment for type of surface was used in the

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Publication of this paper sponsored by Committee on Surface Properties-Vehicle Interaction.

noise prediction. The measured L_{10} noise level was then compared with the predicted level.

RESULTS

Reference Car Noise Measurements

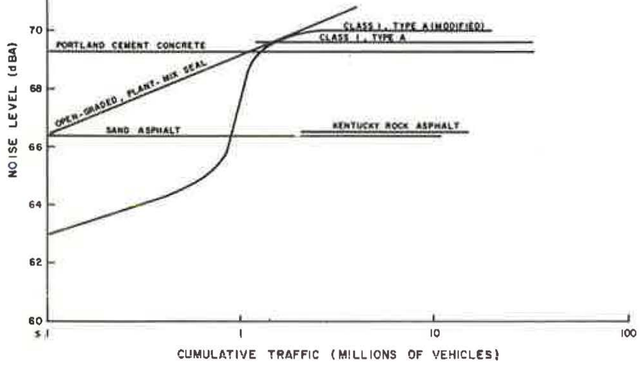
After preliminary testing of several locations in which each type of pavement was involved, a relationship was found between noise level and cumulative traffic. A plot of noise level versus cumulative traffic volume was made for each type of pavement by using the noise level found at 72 km/h (45 mph). A summary of data on noise level versus cumulative traffic for all types of pavement surfaces (except chip seals) is shown in Figure 1. A total of 87 tests at 63 locations were conducted.

Sand asphalt and Kentucky rock asphalt surfaces are the only surfaces that maintained a low noise level (about 66 dBA) with increased cumulative traffic. Class 1, type A (modified) bituminous, chip seal, and open-graded plant-mix surfaces all were relatively quiet sometime during their service life, but the noise level of each increased to between 69 to 70 dBA as the cumulative traffic increased. Class 1, type A (modified) bituminous surfaces were smooth and dense when placed but became noticeably polished after the cumulative traffic reached about one million vehicle passes. Also noise levels increased on open-graded plant-mix surfaces with time. On new chip seal surfaces, the exposed aggregate produced high levels, but noise levels dropped as the aggregate wore and the surface bled. Finally, the older surfaces began to crack and break up, and the noise level again rose. Chip seal surfaces are not included in Figure 1 because they are placed only on low-volume roads and are expected to endure for a limited time. Portland cement concrete and class 1, type A bituminous surfaces maintained a relatively constant noise level (69.5 dBA). Tests on transversely grooved portland cement concrete surfaces yielded a noise level of about 73 dBA.

Table 1. Recommended noise level adjustments for various types of surfaces.

Surface Description	Car (dBA)	Truck (dBA)
Grooved portland cement concrete	+4	0
Normal surfaces		
Class 1, type A bituminous concrete	0	0
Class 1, type A (modified), bituminous concrete	0	0
Portland cement concrete	0	0
Open-graded, plant-mix seal	0	0
Chip seals	0	0
Smooth surfaces		
Kentucky rock asphalt	-3	0
Sand asphalts	-3	0

Figure 1. Effects of cumulative traffic on noise levels of various pavement surfaces.



A few readings were obtained for surfaces that were unusually cracked and bumpy. These surfaces might be classified as rough and were not included in any of the preceding types of surfaces. These rough surfaces had an average noise level of about 72 dBA.

To ensure that the reference car noise data were representative of the average car, we compared results from a previous vehicle noise survey (5) to the reference car data. The survey was conducted on class 1, type A bituminous and portland cement concrete surfaces for various speed-limit locations. The data at 72-km/h (45-mph) and 97-km/h (60-mph) speed limit locations were compared to the reference car data for the corresponding speeds. The survey vehicles were not traveling at exactly the speed limit, but the large number of vehicles in the survey should make the comparisons valid. The median automobile noise level was 68 and 74 dBA for 72 and 97-km/h (45 and 60-mph) speed limit locations respectively. This compares to reference car noise levels of 69.5 and 74 dBA at the corresponding speeds. From this comparison, one can see that the reference car was representative of the average car.

Noise Measurements Inside the Reference Car

To determine the differences in noise levels for occupants of vehicles driving on various surfaces, we took measurements inside the reference car. In all cases, the vehicle speed was 72 km/h (45 mph). The sound-level meter was held about 150 mm (6 in) above the backrest of the front seat, which closely corresponds to ear level. The slow response of the sound-level meter was used so that variations in the noise could be minimized. The average noise level over a uniform stretch of highway was tabulated for each type of pavement. From 3 to 14 locations were tested for each type of surface. The readings were averaged. The sand asphalt and Kentucky rock asphalt surfaces gave the lowest noise levels (65.3 dBA). The other types of surfaces were ordered in the same way as the data obtained from outside the reference car (Figure 1).

Noise measurements were also made inside the car on some bridge decks. Two bridge decks that had been grooved were compared to one ordinary deck. The average readings for the grooved decks were identical to the average of grooved concrete pavements. Grooved decks gave readings approximately 3 dBA higher than ordinary decks.

Noise Recordings

A total of 260 noise recordings taken on various surface types were compared to predicted values. The predicted L_{10} noise levels [based on NCHRP Report 117 (3) with Kentucky correction nomograph] were compared with measured values. The actual and predicted L_{10} values for class 1, type A bituminous concrete; worn class 1, type A (modified) bituminous concrete; portland cement concrete; sand asphalt; open-graded, plant-mix seal; and Kentucky rock asphalt surfaces were within ±1 dBA. New class 1, type A (modified) surfaces were nearly 5 dBA under the predicted levels. This, however, is not indicative of the long-term noise level. Also, at these locations, there were a large number of smaller, quieter trucks, which resulted in actual noise levels below the predicted levels. Reliable noise recordings for the grooved concrete surface could not be obtained because the only section that had been opened to traffic was two lanes of a four-lane highway. The very low traffic volumes on the chip-seal surfaces made noise recordings unreliable. Some recordings were also taken on some surfaces that were very cracked and bumpy and may be classified as rough. These rough surfaces had actual L_{10} noise levels that were approximately 5 dBA above the predicted values.

Reference Truck Noise Measurements

The truck used was a single-unit, two-axle, six-tire truck. It was loaded to approximately 8165 kg (18 000 lb) on the rear axle. Measurements were taken on a new, unopened section of Interstate Highway. There were two sections of grooved concrete and one section of ordinary concrete. The data were taken 15 m (50 ft) from the center of the lane tested. At 72 km/h (45 mph), the truck gave readings of 80.7 dBA and 81.9 dBA on the two sections of grooved concrete and 81.2 dBA on one section of ordinary concrete. The grooved concrete did not cause additional noise to be emitted by the truck.

SUMMARY AND CONCLUSIONS

To develop adjustment factors for noise levels on various types of pavement, we considered the individual vehicle readings and the traffic stream recordings. The individual vehicle noise readings showed that, after a traffic exposure of 10 million vehicle passes, only Kentucky rock asphalt and sand asphalt surfaces give consistently low values (about 66 dBA). Grooved concrete exhibits noise levels of about 73 dBA. All other surfaces show normal noise levels of 69 to 70 dBA. Thus, the car adjustment was considered to be +4 dBA for the grooved concrete surfaces. An adjustment of -3 dBA was considered appropriate for cars on Kentucky rock asphalt and sand asphalt surfaces.

The truck adjustments were determined from noise recordings on the different types of surfaces as well as the reference truck data on grooved concrete. By comparing predicted with measured noise recordings, several conclusions were reached. Actual values on new class 1, type A (modified) surfaces were quieter than predicted, but worn class 1, type A (modified) surfaces showed noise levels similar to those predicted. The other types of surfaces showed very little differences between predicted and measured levels. Thus no adjustment was considered necessary for trucks on the surfaces for which noise recordings were taken. The reference truck data indicated that no adjustment for trucks was necessary for grooved concrete surfaces.

There is a definite advantage in considering adjustments separately for cars and trucks. In most cases, the L_{10} noise level for trucks predominates in the traffic stream. However, when car noise predominates, a separate adjustment for cars would make predicted levels more accurate. The recommended adjustments for car and truck noise levels are given in Table 1.

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