Diamond Grinding for Roadway Noise Control

Areg Gharabegian and **Emery Tuttle,** Parsons Corporation, Pasadena, California

The results of grinding a roadway to reduce the noise from tire/pavement interaction are presented. The study concluded that a diamond ground roadway surface would produce lower tire noise than a surface that had longitudinal grooves. Single vehicle pass-bys and average noise level measurements were used for this evaluation.

A study was conducted to determine if the noise generated by the interaction of tires and pavement surface would be lower for a PCC (Portland Cement Concrete) surface that is diamond ground as opposed to a surface that has longitudinal grooves. Demonstrating that the traffic noise levels can be lowered due to the diamond grinding would provide justification for diamond grinding Route 85 in San Jose, CA to lower the noise levels in adjacent areas. Because there is a truck ban for Route 85, the main traffic noise source is from the interaction of tires and pavement surface. Parts of Route 85 are depressed and there are soundwalls along the roadway wherever there are noise sensitive receptors. Previous noise studies have indicated that raising the height of the existing soundwalls would not be effective in further reducing the noise levels.

Vehicle pass-by measurements are needed on both types of road surfaces to determine the acoustic benefit of the surface type. Ideally, it would be desirable to perform 'before' and 'after' measurements so that the same location could be measured with both road surface types. Route 85 could not be considered at the time of this study as a possible site to conduct the noise measurements because there are no current plans to diamond grind its pavement. A portion of Route 101 in Sonoma County, CA was used for conducting noise measurements.

Site Selection

A search was conducted to locate a project that included diamond grinding of an existing PCC grooved surface roadway in California. The need for grinding a roadway surface only occurs when the current surface has been worn smooth. A smooth surface would not make an adequate comparison to the existing Route 85 surface. Therefore, it was decided that the 'before' and 'after' measurements would have to be at two different locations close to each other and with similar characteristics.

Considerations for an appropriate site for vehicle pass-by measurements included the need of distinct pavement grooves with little wear. The site had to be located in a rural area so that light traffic conditions were present. The geometry of the site had to be relatively flat so that measurement microphones could be placed at 7.5 and 15 m (25 and 50 ft) from the centerline of the outermost lane of travel without obstructions or interference between the microphone position and passing traffic. Finally, a clear line of sight for a distance of 90 to 120 m (300 to 400 ft) before and after the microphone position was needed.

These considerations led to the selection of a measurement location along northbound U.S. Highway 101 near the City of Geyserville. In this area there is an adequately long section of longitudinally grooved pavement with a nearby section of smooth, diamond ground pavement. The measurement site for the grooved pavement surface ('before') was selected based on its similarity to the highway areas where the road surface was diamond ground ('after'). The two sites were within several miles of each other. Figures 1 and 2 show the surface of Route 101 in the area with longitudinal grooves and areas with diamond grind, respectively.

Figure 1. Longitudinal grooves of Route 101 at the test segment.

Figure 2. Route 101 surface after diamond grinding.

Measurement Procedure

Single vehicle pass-by spectrum noise measurements were conducted simultaneously at the site (Site 1) with longitudinal grooves and the similar site that was diamond ground (Site 2). Simultaneous 15 min-long average noise level (L_{eq}) measurements were also conducted at the two sites.

Pass-by Spectrum Noise Measurements. The objective of the measurements was to collect data for individual vehicle passbys. Light traffic conditions at this location of U.S. 101 made this possible. A Larson Davis model 2900 2-channel real-time spectrum analyzer (RTA) was set up to measure and store 1/2-sec intervals of the sound level time history for both the overall broadband and 1/3-octave frequency bands. Channel 1 recorded the noise level at a distance of 7.5 m (25 ft) from the centerline of the outside lane of travel of northbound U.S. 101. Channel 2 recorded noise levels at 15 m (50 ft). Figure 3 shows a schematic diagram of the arrangement of the noise measurement instrumentation. Figures 4 and 5 show the measurement site for the longitudinally grooved (Site 1) and Figures 6 and 7 show the measurement site for the diamond grind (Site 2).

Two documents were used as a guideline for procedures to conduct the measurements. The first was a U.S. DOT document entitled "Measurement of Highway Related Noise," and the second was an ISO standard entitled, "Acoustics – Measurement of the Influence of Road Surfaces on Traffic Noise 11819-1."[1,2]

A pass-by was recorded when an individual vehicle passed

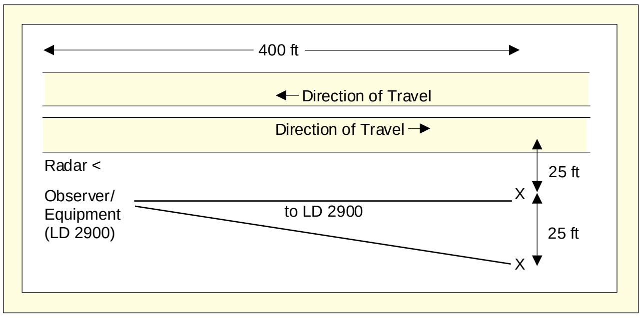

Figure 3. Schematic diagram of the measurement instruments.

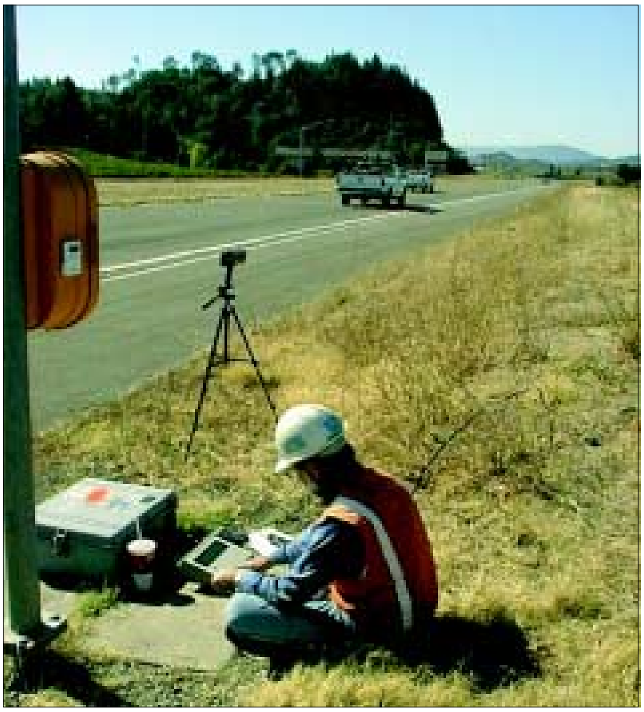

Figure 4. Measurement instruments and the operator.

Figure 5. Microphone at 7 m (grooved Site 1).

Figure 6. Microphone at 7 m, looking south (diamond grind Site 2).

Figure 7. Microphone at 7 m, looking north (diamond grind Site 2).

in the outside lane with a minimum of 110 m (350 ft) of spacing between it and other vehicles. When the vehicle passed the observer point, the recording was started and continued until the sound level decayed as much as possible before the next vehicle pass-by. The vehicle type was noted, along with its speed according to the radar gun and a notation of whether or not the pass-by was a 'clean' measurement (i.e., little or no interference from other vehicles on the nearby northbound entrance ramp or from southbound vehicles). Five vehicle types were noted in the field observations as follows: 1) passenger cars, 2) sport utility vehicles (SUV), 3) pickup trucks, 4) minivans and vans, and 5) medium trucks.

In addition to the five vehicle categories, a specific test vehicle was also used to perform repeated passbys so that measurements could be made on a vehicle of known type and operating conditions. The test vehicle was a Ford Taurus.

Simultaneous 15 Minute L_{eq} Measurements. The purpose of these measurements was to determine an overall average traffic noise level over a period of time at the grooved and diamond ground sections of the road. Larson Davis 870 sound level meters were used for these measurements. Microphones of the measurement systems were positioned 10 m (33 ft), 15 m (50 ft), and 33 m (107 ft) from the centerline of the outside travel lane of northbound U.S. 101. Several sets of 5 and 15 min long L_{eq} and statistical levels measurements were conducted using two Larson Davis 870 sound level meters. During the measurements it was observed that the heavy trucks were about 10% of the total volume of the traffic. Because the exhaust stack and engine are the major noise sources on a heavy truck, the roadway surface would have much less effect on the overall heavy truck noise levels than it would have for cars. Since there is a truck ban for Route 85, it was decided to conduct half of the measurements without heavy trucks. During some of the measurements, systems were paused each time a heavy truck was approaching the monitoring sites. During the 15 min period, the passing traffic was either video taped or manually counted, so that the traffic could be classified by vehicle type.

All 5 and 15 min long L_{eq} levels measured at 15 and 33 m were disregarded because they were not conclusive. These measurements were affected by the on-ramp and frontage road traffic at Site 2. Traffic on the frontage road and on-ramp affected measurements due to their proximity to the microphones. Another issue that had an adverse effect on the measurements was the large number of heavy trucks traveling on U.S. 101. On average, every minute there is one heavy truck going in each direction on U.S. 101. At the location further away from the roadway, heavy trucks become the dominant noise source. Because the dominant noise sources from heavy trucks are the engine and stack, the roadway surfaces have much less effect on the heavy truck noise levels than it has on cars. Therefore, once the heavy truck noise becomes the domi-

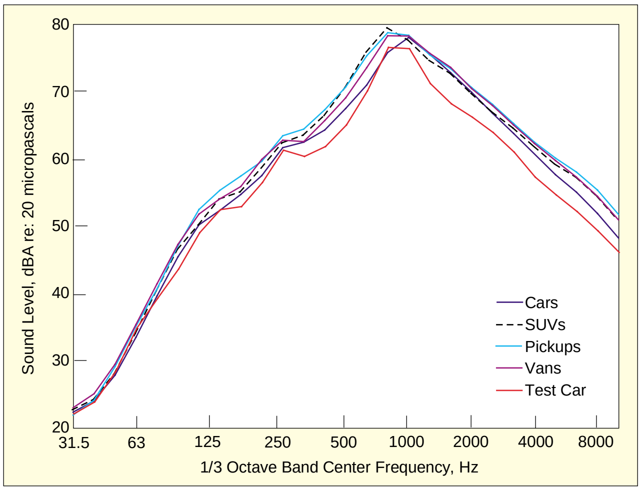

Figure 8. Average A-weighted spectrum of vehicle passbys on longitudinal grooved pavement surface at 7.5 m.

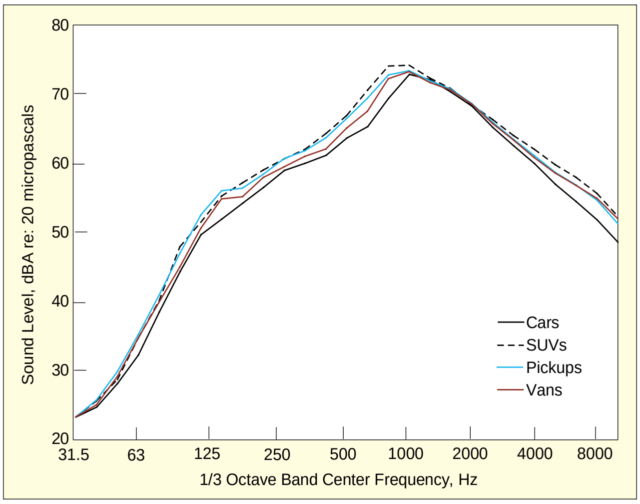

Figure 9. Average A-weighted spectrum of vehicle passbys on diamond grind pavement surface at 7.5 m.

nant noise source; the measured L_{eq} levels at the grooved and grind sites become almost equal. The measured 15 min L_{eq} levels at the 10 m location show some noise reduction between groove and grind sites. Measurements at these two locations were not affected by the on-ramp or frontage road traffic. Table 1 summarizes the results of the simultaneous 15 min average noise measurements (L_{eq}) conducted at 10 m. The noise drop between these two sites may also not be conclusive due to the small number of samples at these sites.

Atmospheric Conditions. Throughout the single pass-by field measurements, atmospheric conditions were monitored. At 15 min intervals, the temperature, humidity, wind speed and wind direction were recorded. The measured atmospheric data show favorable conditions for the noise measurements. Because wind speeds were low, the change of wind direction should not have affected the results of the measurements.

Table 1. 15 minute overall measurements at 10 meters (33 feet).

Description of Measurement	Longitudinally Grooved	Diamond Ground	Difference
With Heavy Trucks:			
1st 15-min L_{eq} measurement	77.7 dBA	74.7 dBA	–3.0 dB
2nd 15-min L_{eq} measurement	77.3 dBA	74.6 dBA	–2.7 dB
Without Heavy Trucks:			
1st 15-min L_{eq} measurement	75.4 dBA	71.3 dBA	–4.1 dB
2nd 15-min L_{eq} measurement	74.5 dBA	70.7 dBA	–3.8 dB

Notes:

1. All sound levels were measured using A-weighting and a slow detector response.
2. The traffic volume throughout each of the simultaneous measurements was approximately 500 vehicles per hour in the northbound direction.
3. The measurement system was paused when a heavy truck was close enough to the microphones to influence the measurement results. This effectivley removed heavy truck noise from the 15 minute average levels.

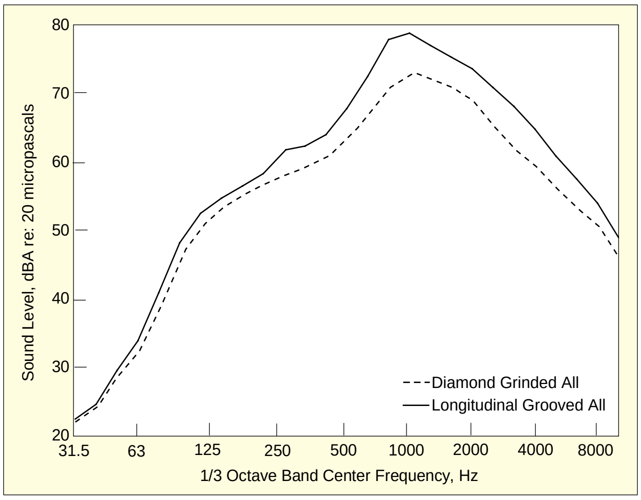

Figure 10. Comparison of the average A-weighted spectrum for the average of all vehicle types at 7.5 m.

Measurement Analyses and Discussion

The results of the single vehicle pass-by noise measurements indicated the differences in tire and pavement interaction noise levels for different types of pavements. The single vehicle pass-by noise measurement data were downloaded to a computer spread sheet for detailed analysis. The data were then sorted by vehicle type and speed. Any of the recorded events that could not show a minimum 6 dB decrease on both sides of the event's maximum sound pressure level were discarded. The 6 dB decrease was used as an indicator of whether or not the vehicle noise was contaminated with the noise from other vehicles or other sources present in the environment. Table 2 lists the number of vehicles in each category that were considered acceptable, and the range of measured noise levels for different sets of measurements at 7.5 and 15 m locations. There were only a few medium truck passbys during each of the measurement sets. Because there were an insufficient number of me-

Table 2. Average sound pressure levels for vehicle pass-bys.

Vehicle Type	No. of Events	Range of A-Weighted L_p, dBA	No. of Events	Range of A-Weighted L_p, dBA
Distance 7.5 meters (25 feet)				
Passenger Car	229	79-89	243	73-84
SUV	45	83-89	50	77-84
Pickup	81	82-89	101	75-84
Vans & Mini-Vans	28	82-88	36	76-82
Test Vehicle[1]	9	82-83	8	77-81
All Vehicle Types	383	79-89	430	73-84
Distance 15 meters (50 feet)				
Passenger Car	129	73-82	155	68-79
SUV	30	75-82	35	71-79
Pickup	62	75-81	79	71-81
Vans & Mini-Vans	17	75-81	26	71-76
Test Vehicle[1]	2	73-75	5	71-76
All Vehicle Types	238	73-82	295	68-81

1. Test vehicle counts are included in the passenger car counts.

Table 3. Statistical By-Pass Index (SBPI), dB.

Location	Longitudinally Ground Pavement	Diamond Ground Pavement	Difference
7.5 meters	83.1	77.4	5.7
15 meters	76.3	72.0	4.3

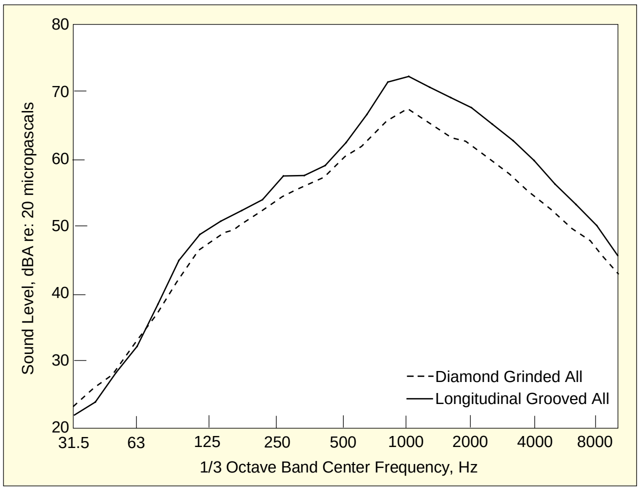

Figure 11. Comparison of the average A-weighted spectrum for the average of all vehicle types at 15 m.

dium truck passbys, medium trucks were not included in the analysis. Heavy trucks were not considered for the study either because of the heavy truck ban on Route 85. While no correlation was found between vehicle type or speed and maximum sound level for this size sample, the results indicated that the lowest pass-by noise measurement recordings were from passenger cars.

Due to favorable atmospheric conditions, no adjustments to the measured noise data were necessary. There were some minor speed variations between different sites and categories but these speed differences should not affect results of measurements.

Figures 8 and 9 show graphs of the average 1/3-octave band sound pressure levels for each vehicle type and the test vehicle for measurements at 7.5 and 15 m (25 and 50 ft) for each of the measurement sets. Results in Table 2 and different graphs show the traffic noise reduction, which resulted from tire and pavement interaction for two different types of roadway surfaces. Noise reductions shown in the graphs should be representative of noise reduction that can be achieved by diamond grinding Route 85.

The averages of all the maximum measured single pass by overall noise levels for 7.5 and 15 m were compared for the grooved and diamond ground surfaces. The results show that there is approximately 6 dBA noise reduction at 7.5 m due to the diamond grinding. The results of the measurements (Sites 1 and 2) also show that there is about 5 dBA noise reduction at 15 m. Figures 10 and 11 show comparisons of the average 1/3-octave band sound pressure levels for all the vehicle categories at 7.5 m (25 ft) and 15 m (50 ft) for Sites 1 and 2, respectively.

According to ISO 11819-1, Part 1, Section 9.5, the standard requires an index calculation in order to obtain an aggregate (overall) level of road surface influence on traffic noise at the 7.5 m (25 ft) microphone position. This index called Statistical Pass-By Index (SPBI) allows comparisons to be made with other measurements that were for other projects. The ISO standard provides for inclusion of heavy vehicle types, not included in these measurements because of the heavy truck ban on Route 85. These values were calculated based on the formula given in the ISO standard, which was modified for Category 1 vehicles only in the 'High' road speed category:

$$\text{SBPI} = 10 \times \log_{10}(W \times 10^{L/10})$$

where:
W = weighting factor of 0.7 for cars
L = average sound level for Category 1 vehicles.

Table 3 shows the calculated SPBI factors for grooved and ground cases at 7.5 m (25 ft) and 15 m (50 ft). Results of the calculation indicate approximately a 4 to 7 dB drop in SPBI due to grinding.

Conclusions

This study was conducted to determine if the noise generated by the interaction of tires and pavement surface would be lower for a PCC roadway surface that had been diamond ground as opposed to a surface that had longitudinal grooves. The results of this study indicated that the average noise drop of the maximum pass-by noise levels is approximately 6 dB at 7.5 m (25 ft) and 4 dB at 15 m (50 ft). Therefore, the single vehicle 'pass-by' measurements indicate noise from tire/pavement interaction is likely to be perceptibly quieter for a diamond ground pavement vs. a pavement with longitudinal grooves. This is especially applicable to a roadway where there is a heavy truck ban or little truck traffic. At a roadway where there are large numbers of heavy trucks a noticeable noise reduction may not be achieved because the main truck noise comes from the engine and exhaust stack. Measurement results show that the noise drop starts at 160 to 200 Hz, but the main drop is between 500 and 2000 to 4000 Hz.

The results of the 15 min simultaneously measured average noise levels (L_{eq}) at 15, 30 and 33 m were not conclusive and they indicate almost equal levels for grooved and ground roadway surfaces. However, the 15 min L_{eq} measurements at 10 m (33 ft) indicate that there is about 3 dB noise reduction due to the diamond grinding for all vehicles, including heavy trucks. When heavy trucks are excluded, the noise reduction is about 4 dB. The results of the 15 min L_{eq} at 10 m may also be inconclusive due to the lack of sufficient measured levels at this distance.

References

1. USDOT, 1996, "Measurement of Highway Related Noise."
2. ISO, 1997, "Acoustics – Measurement of the Influence of Road Surfaces on Traffic Noise, 11819-1."

The authors may be contacted at: areg.gharabegian@parsons.com.