Analysis of Traffic Noise Before and After Paving With Asphalt-Rubber

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ABSTRACT: *Altering the pavement surface can reduce noise generated by traffic on a highway. Aged Portland cement concrete pavements (PCCP) are commonly altered or improved by grinding or by sawing grooves into the surface to provide better friction characteristics and in some cases to reduce rolling tire noise. Asphalt concrete surfaces are milled and replaced with a new asphalt surface. Recent improvements to urban freeways in Arizona have used thin (2.5 cm or less) open graded friction courses manufactured with asphalt-rubber binder where the binder is comprised of 80% asphalt and 20% ground tire rubber. The thin layers of Asphalt-Rubber Open Graded Friction Courses (A-R OGFCs) placed by the Arizona Department of Transportation have been noted for long lasting performance while improving the ride characteristics of aged PCCP. Additionally, although it was not placed for this purpose, the rubberized asphalt surfaces give significant reductions in traffic noise when compared to adjacent Portland concrete cement surfaces. In this study the reduction has been noted to be from 9 to 6 dB (A) at distances from 15-120 meters (50-400 feet) from the highway.*

KEY WORDS: *Asphalt-Rubber, Open-Graded Friction Course, Noise, Thin, Durable, Decibels.*

1. Introduction

The generation of noise from highway traffic has become an significant concern for highway departments, highway users and members of the community that live and work near highways. The greatest concern focuses upon on how the noise can be reduced. Typical noise mitigating efforts employed by highway departments involve the construction of barriers that reduce the noise level that is propagated into certain areas. These sound walls do not actually reduce the noise levels produced on the highway, but they prevent some of the noise from entering areas nearby. Another concern is that traffic noise levels have grown beyond projections and have overcome the effectiveness of soundwalls that have already been constructed. Many of the walls' foundations were not designed for an additional increase in height to mitigate the noise problem, so must be completely rebuilt.

Beside soundwalls, other methods of reducing traffic noise include: the production of vehicles with lower noise emissions from the exhaust systems, mechanical operations, and noise reducing aerodynamic design, the manufacturing of tires with tread designs that reduce the noise generated by the rolling tire and pavement contact, and by altering the surface texture of the pavement. Private industry has met the consumer demand for quieter products, but highway agencies have not been able to make a quieter product without considerable cost, especially where highways have already been constructed and are already in use.

Individual consumers have much more flexibility in the purchase decisions that they make. For highway agencies, material cost and long-term performance are the driving forces to many pavement and roadside geometric designs. Additionally, many pavements now in service were built with specific funding programs that did not include funds for maintenance or future improvements. Highway owners must use a very limited and ever shrinking pool of maintenance dollars to fund improvements to old roadway assets. Presently, because of the lack of data on the sustained noise reduction achieved by various surface treatments, federal assistance can only be used to fund the construction of noise barriers under current policy. [FHA 95]

The use of the AR OGFC material by ADOT was adopted to provide a uniform surface to capacity expansions made to the urban interstate system. The AR OGFC allowed the old existing PCCP that was performing well to be covered side by side with the new PCCP, which was also covered. This strategy provided a smooth and uniform surface with the same skid resistance and drainage characteristics for both the new and old pavement sections and covered and protected the horizontal and longitudinal joints in the PCCP. This strategy was used in 1990 on Interstate 17 and the pavement section is still in service with very little maintenance. [MOR 00] The first use of an AR OGFC by ADOT occurred in 1975 on State Route 87, the first application on PCCP occurred in 1988 on I-19. Based on the experience from these early projects, ADOT was comfortable with using the thin (2.5 cm, 1 in), AR OGFC material.

ADOT did not use this material as a means to reduce the highway noise. However, this phenomenon has been observed and commented upon by the members of the travelling public and communities neighbouring the highways. The differences in noise generation between the surfaces was subject to an extensive analysis in 1995 where the AR OGFC was 4.7 dB less than the PCCP and the AR OGFC experienced a 1 dB increase between 1988 and 1992. [HEN 96]

One of the purposes of this study is to gather noise data to be used as a historical reference for future studies at the same collection points to help determine the sustained reduction achieved by the AR OGFC, if any. In turn this data can be used to develop a new noise policy employed by the Federal Highway Administration to allow funding of noise mitigating activities that include resurfacing of aged PCCP with AR OGFCs. It is not intended to be used for traffic noise modelling purposes.

The current traffic noise model does not include an input or variable for this pavement type, it does allow for the input of DGAC, OGAC and PCCP. However, Dense Grade Asphalt Concrete and PCCP are considered the average, recommended for use in almost all modelling situations. The noise model is used to calculate the height needed for effective noise wall construction based upon other factors such as traffic volumes, types of vehicles, the number of lanes, the types of contours along the roadway, existing noise barriers and the material composition of the barriers and roadside vegetation. The omission of a variable for the pavement surface is largely due to the fact that surface type noise data was not readily available at the time the model was developed. Additionally, pavement surface alteration was not considered to be a viable option because it could not be proven to result in a permanent 5dB reduction, which is one of the criteria to be used when federal funding is considered for noise mitigating activities.

It should be noted that the federal program for noise barrier construction has averaged more than $118 million annually in the last five years. [FLE 00] According to FHWA policy, noise barriers or sound walls are expected to reduce the amount of noise propagating beyond the barrier by 1 dB for every two feet in height. So then, logic would seem to imply that noise barriers could be reduced by 2 feet for every 1 dB reduction in traffic noise. According to the FHWA, a two-foot reduction in noise barrier construction would provide a cost savings of 16% or about $19 million each year in the U.S. [FHA 00]

2. Data Collection

Noise data was collected at three locations before and after paving with the thin AR OGFC. The meter used to capture the noise data was a data-logging, type 2 sound meter, model number 840013, manufactured by Sper Scientific LTD. The meter was calibrated by the manufacturer prior to use and meets the criteria set in ANSI S1.4 as approved by the FHWA in the Noise Barrier Design Handbook. [FLE 00], [ANS 97] The meter was set for frequency weighting "A" commonly used in traffic noise analysis. A windscreen provided by the manufacturer was used in all recordings. The noise meter recorded the dB level every six seconds, or ten times a minute. The meter was set to record for no less than fifteen minutes at each location along the highway so that no less than 150 data points where collected. The data points were then averaged and the high point and low points were noted. The data was collected on regular, non-holiday weekdays between 11:00 am and 1:00 pm. The traffic appeared to be typical in terms of vehicle types and total volume. However, the "after" traffic appeared to be moving at a higher speed and had an additional lane available for travel. The measurements before paving with the asphalt-rubber material were made on May 29, 2002. The date after paving with asphalt-rubber was June 17, 2002.

Environmental data, except for barometric pressure, was collected onsite via a Lutron LM-8000 4 in 1 meter (Anemometer, Hygrometer, Light Meter and Thermometer), which provided the air temperature, relative humidity, and wind speed. The sunshine and barometric pressure were records provided by the National Weather Service from the Phoenix Sky Harbor Airport observation station 8.5 km (5.2 miles) away from the site. The environmental conditions for both days were similar and typical for the time of year.

Table 1. Environmental Data

Environmental Factors	Before (05-29-02)	After (06-17-02)
Temperature	39 C (103 F)	40 C (105 F)
Relative Humidity	5%	2%
Wind	10 kph (6 mph) West	5 kph (3 mph) West
Barometric Pressure	28.58 inches	28.57 inches
Sunshine	100%	100%

Three measuring points were selected based on their accessibility and ease in identification for future reference. Also, the locations were selected to represent typical conditions, primarily in the ambient noise level and roadway geometry. All of the locations are approximately in line on a north to south axis, 180 meters west of Kyrene Road. The meter was positioned on the North side of the highway at all locations so that the westbound lanes were the closest to the meter.

The first location was near the shoulder against a retaining wall. A small rise exists between the shoulder and the retaining wall and a jersey barrier is on the pavement edge between the retaining wall and the traffic. The location is represented in Figure 1.

Figure 1. Location one, near the shoulder before paving with AR OGFC.

It is noted that the additional lanes that were constructed in the widening project were not available for traffic in the before measurements, but were available in the after measurements. The before measurements include three traffic lanes. The after measurements include three traffic lanes, an HOV lane and a merge and exit lane for Mill Ave and Priest Drive. This location provided decibel readings from traffic about 15 meters away and about 35 meters from the centerline between the West and East bound traffic lanes. The after measuring point is actually closer to the traffic as can be seen in Figure 2.

Figure 2. Location one after paving with AR OGFC and widening by two lanes

The second location was against the soundwall at the top of the earthen berm held in place by the retaining wall below that can be seen in Figures 1 and 2. This location is elevated above the traffic and about 30 meters from the shoulder. Location two is represented in Figures 3 and 4, before and after paving with AR-OGFC.

Figure 3. Location two before paving with AR OGFC.

Figure 4. Location 2 after paving and widening.

The third location was in a residential area at the intersection of Riviera Drive and Farmer Avenue. Riviera is the first street south of and parallel to the freeway. The location was on the sidewalk on the south side of Riviera Dr. so that the street, a row of houses and an alley separated the soundwall and the noise meter, a distance estimated at 120 meters from the traffic. No traffic was observed on Riviera Drive during the recording periods. A view of the house across the street with the soundwall and freeway light pole visible in the background is provided in figure 5.

Figure 5. House across the street from the corner of Riviera and Farmer, location 3.

These locations were used for both the before and after readings. The table below provides the averages in decibels for each location before and after paving with the asphalt rubber.

Table 2. Noise Data in Decibels (A weighted)

Location	Before	After	Decrease
Shoulder (15m)	79.8	72.6	7.2
Soundwall (30m)	76.6	67.1	9.5
Residential (120m)	51.7	45.6	6.1

These are significant reductions in the traffic noise as a result of minimizing the tire/pavement noise generation. A reduction of 3 dB is equivalent to doubling the distance from the noise source. A reduction of 10 decibels is equivalent to halving the overall loudness. For vehicle speeds above 40 m/h (55 km/h) tire noise is the dominant factor. [SAN 02]

Traffic volumes and mix were recorded on videotape when the noise data was collected. The videotape was analysed later to obtain the traffic data, which is summarized in Table 3. The traffic data is only for the westbound lanes, closest to the measuring points. The eastbound traffic was observed but not counted. It appeared to be similar in volume and type, and free-flowing, or typical traffic for a non holiday, work, weekday.

Table 3. Traffic Data

Traffic Count (15 Min)	Total	Type 1-3	Type 4-13
Before	1089	905	184
After	1170	989	181

Actual vehicle counts were conducted for five minute intervals during the 15 minute noise measuring periods in the before and after conditions at locations 1 and 2 (nearest the roadway) and then estimated based on the samples taken. The vehicle types were partially separated using the US DOT type classification depicted in Figure 6. [HO 02]

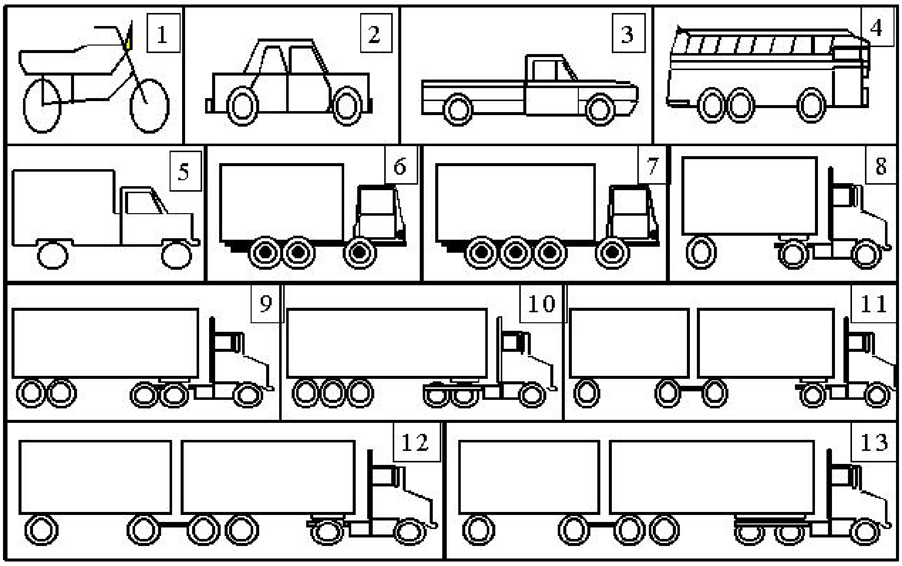

Figure 6. FHWA Vehicle Classification

Although the vehicles were not subject to any metered speed determination, such as radar or timed between points on the video tape, it appeared to move at a higher speed in the after condition with the smoother surface and additional lanes. Typically, tire noise will increase with higher speeds. [SAN 02] A 3 dB difference is noted between 89 kph and 105 kph (55 mph and 65 mph) for both pavement types, the higher speed has a higher dB reading. [HEN 96]

3. Noise Inside a Vehicle

At the request of the RPA Technical Advisory Board, noise data was collected from within a vehicle travelling upon the different surfaces. This was accomplished by driving with the noise minimized within the vehicle by turning the air conditioning and radio to the off position and by keeping the windows closed in the rolled up position. Environmental data were not noted, but the conditions were the same for all of the noise readings as they were conducted on the same day within minutes of each other. Traffic conditions were typical, but traffic counts were not conducted as the test vehicle was moving with the traffic at a constant rate of 105 km/h (65 mph). The vehicle used in this analysis was a 1993, four door, Cadillac Seville. Although it is clear that the amount of noise that enters the passenger compartment of any given vehicle will vary greatly depending upon the make and model as well as the type of tires that are on the vehicle, this simple analysis was conducted to determine if a change in the surface would change the noise level inside the vehicle and attempt to define the difference.

These data were collected on the concrete starting at one mile from the concrete/asphalt joint in both the Eastbound and Westbound travel lanes and then continued on for one mile upon the A-R surface. The data was then averaged for the type of surface and the highs and lows were recorded. A table of the results follows:

Table 4. Noise readings in a vehicle travelling upon both surfaces.

Inside Car	Concrete	A-R	Difference
Average	67.0	61.8	5.2
High	72.8	64.4	8.4
Low	64.3	60.1	4.2

The A-R surface reduced the noise level within the vehicle by over 50%, a significant reduction noticeable to the user. It was observed that the noise generated by other vehicles nearby were responsible for most of the variance in the readings on both surfaces. The transverse joints on the aged concrete also appear to add a significant amount of the higher readings, while no joints are present on the new A-R surface. It should be noted that newer concrete surfaces have been designed to minimize the width of joints which helps reduce the generation of tire noise.

Another simple analysis was conducted to determine the contribution of engine noise inside of the vehicle. This was done by positioning the vehicle in an office-building parking lot approximately 60 meters from the nearest access road. While operating, the motor was at idle. No traffic was recorded in the vicinity of the test vehicle the results are displayed in Table 5.

Table 5. Noise readings in a vehicle with motor on and off.

Inside Car	Motor on	Motor Off	Difference
Average dB	46.6	31.7	14.9

Typical noise contributions from different passenger vehicle sources can be summarized as follows: 41% Tire/Road Interaction, 21% Induction System, 17% Unallocated Sources, 12% Exhaust Outlet Flow, 7 % Cooling Fan, 2% Under

Engine Shield. These numbers are expressed as percentage of total sound power. [SAN 02] The rolling tire/pavement noise is considered the most important single noise source.

4. Other Studies

Many studies have recognized the benefit of surface treatments with asphalt materials to help reduce noise, but none have indicated a long term benefit of a five decibel reduction. This is not to say that a five decibel reduction is not achieved, only that most studies have not been design to monitor noise reduction over time. A permanent reduction of five decibels is required by the FHWA for noise mitigating activities that are eligible for federal funding. However the initial reduction as much as 9 decibels have been reported when comparing conventional asphalt concrete OGFCs and PCCP. [WAY 98] Some studies that have explored the duration of noise reduction in rubberized pavements have occurred on city streets. In these settings, the influence of tire noise is diminished due to the slower traffic speeds. However, a measurable reduction has been recorded. Figures 7 and 8 compare two pavements that were over-laid with two different materials, one with an Asphalt-Rubber OGFC the other with Dense Grade Asphalt Concrete (DGAC).

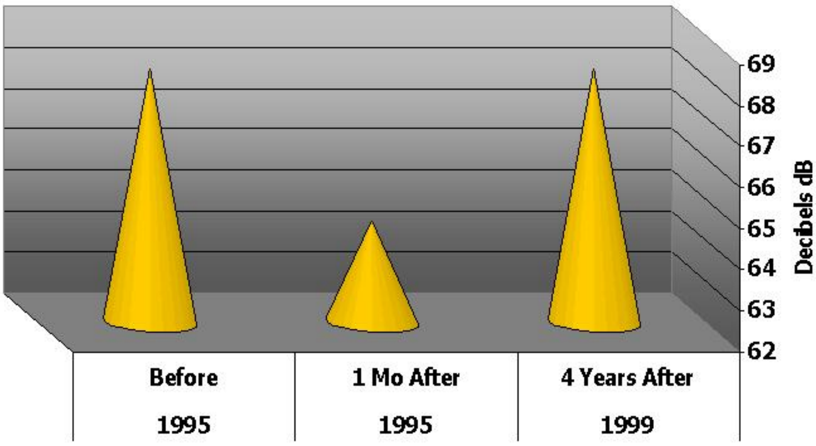

Figure 7. Noise reduction experienced with DGAC after 4 years.

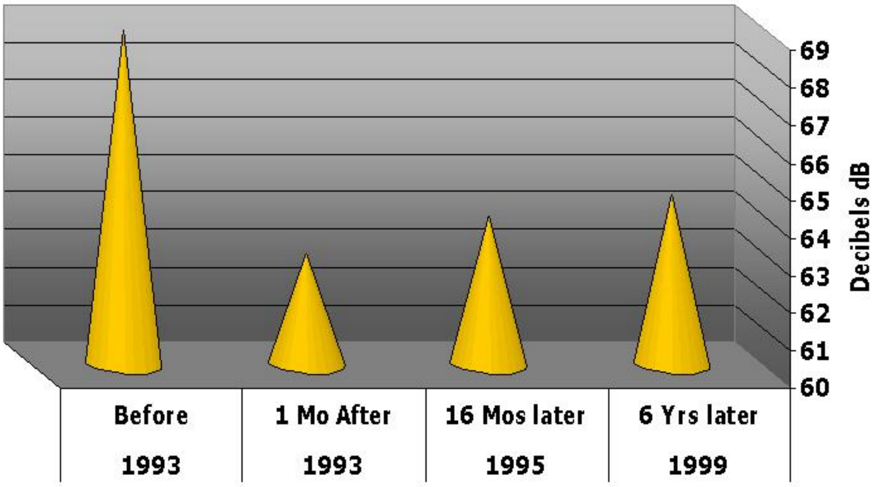

Figure 8. Noise Reduction with AR OGFC after six years.

The two pavements were measured following their placement and then later, as much as six years after the placement. The study was conducted by Sacramento County Department of Public Works to demonstrate that pavements surface texture can be used to mitigate noise and reduce the requirement for noise wall construction. In this study, the sustained reduction after six years was over 4 decibels in the rubber pavement and zero in the conventional pavement. Considering the slower traffic speeds and the predominance of vehicle power train noise, the measured reduction is significant. The authors acknowledge that fact that the deteriorated pavement conditions prior to overlay do contribute to the high decibel levels, however they also note that the DGAC material that was placed became cracked after four years which contributed to the loss of noise reduction. [BOL 99]

A similar before and after study was recently conducted in San Antonio, Texas. The project used a Permeable Friction Course (PFC) to improve the performance of a Continuously Reinforced Concrete Pavement (CRCP). This project was the first of it's kind in Texas.

Results from the Texas Department of Transportation's (TxDOT) project in San Antonio show that an overlay of only 3.8 cm (1.5 inches) of PFC improved the ride quality of the existing CRCP by approximately 61%, improved the skid resistance by over 200%, reduced the noise levels by an average of 14 decibels (dB). The project is located on IH 35 between mile marker 166 (near Walzem Road) and 168 (near Weidner Road). According to Texas DOT report: "the existing CRCP was constructed in the early 1980s. The existing CRCP was generally sound, with only minor distresses. Safety concerns were the primary reasons for placing a hot mix overlay on the CRCP because skid resistance of the existing CRCP was low and the roadway had a history of numerous wet weather accidents. In addition to the safety concerns, the existing CRCP was also extremely rough and, therefore, extremely loud. Complaints were common. In some ways it represented a 'worst- case-scenario' of pavement performance. It was not **comfortable,** but it was **durable**. In other words, it was 'a problem that wouldn't go away.' " [RAN 03]

The mix was designed to have 8.3% binder with 18% crumb rubber content and a total of more than 18% air voids. The following information is excerpted from the Tex DOT Technical Advisory from February 11, 2003.

Before and after ride quality results are presented in Figure 9. Ride quality was measured using the International Roughness Index (IRI) with a high-speed inertial profiler. On average, the roughness was reduced by 128 inches per mile with the PFC overlay. This represents approximately a 61% improvement in ride quality. Research has shown that improving the ride quality of CRCP pavements can significantly extend its performance life by reducing the dynamic loading associated with roughness.

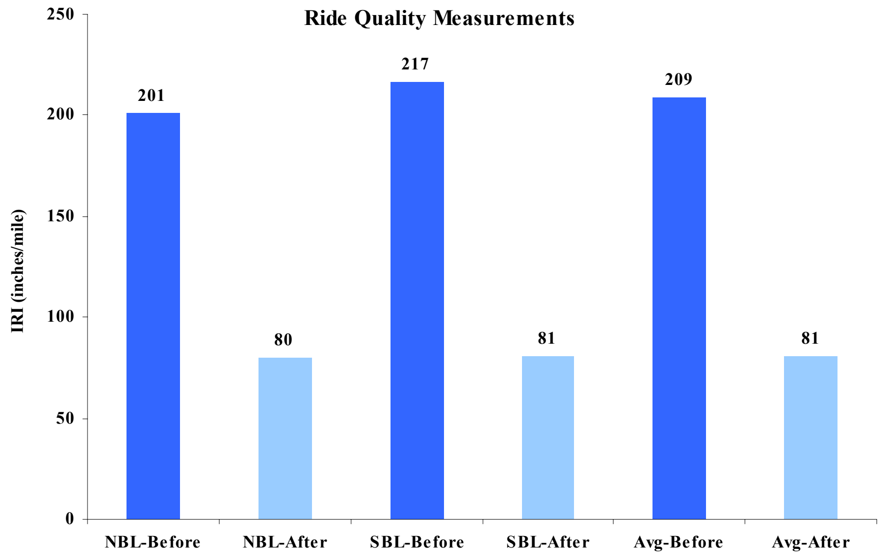

Figure 9. Average Ride Quality Measurements IH 35 San Antonio, Texas

The before and after sound pressure (noise) measurements are presented in Figure 10.

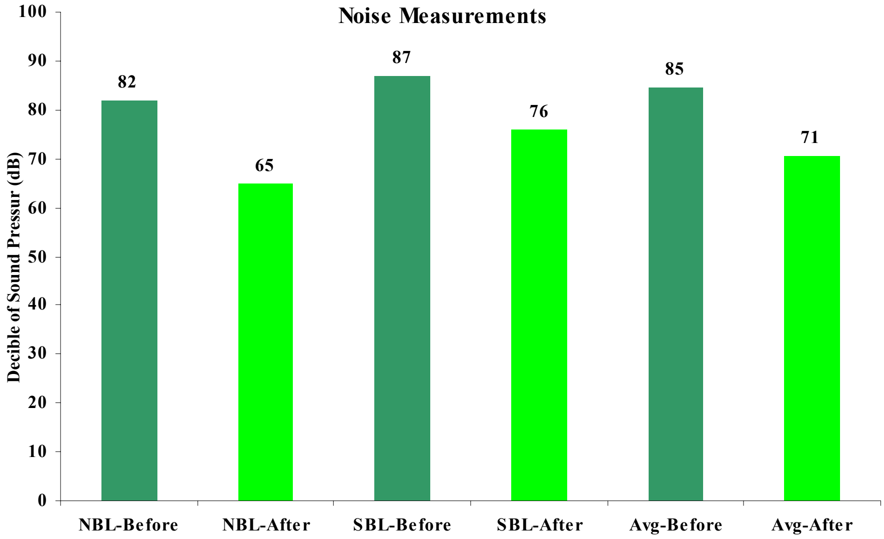

Figure 10. Average Sound Pressure (Noise) Measurements IH 35 San Antonio, Texas

The measurements were taken along the edge of the pavement using handheld noise meters similar to the US 60 project. The results in Figure 10 are the average readings taken at several locations along the project, NBL and SBL indicate the north or south bound lanes. The locations were documented so that the before and after readings could be taken at the exact same locations. On average, the noise was reduced from 85 to 71 dB.

After the PFC overlay on this project, numerous compliments were received related to noise reduction from local business owners and residents. Numerous positive comments were even received on a radio "call-in" talk show.

5. Recent Activities

Based upon the extremely positive public opinion resulting from the US 60 project in Arizona, the municipal governments in and around the City of Phoenix have allocated funding for a system wide AR-ACFC overlay program. The program will pave all of the urban freeway systems that are maintained by the municipal governments (cities and county) to help reduce tire noise. The project will pave 185 km (115 miles) of Portland Cement Concrete Pavements by the end of year 2006. A proposed project plan is submitted as figure 11.

Figure 11. AR-ACFC Overlay Plan for the Phoenix Regional Freeway System.

6. Conclusions

Rolling tire noise caused by contact with pavement can be reduced by controlling the design or type of tires on vehicles or, more easily, by controlling the type of surface on a pavement. AR-OGFCs provide a durable, long lasting, and thin surface layer for PCCP that can be used to significantly decrease the tire/pavement noise. Reduced cracking contributes to the noise reduction in pavements. This simple study demonstrates that immediate relief from noise pressures can be obtained by surfacing PCCP with a thin layer of AR OGFC with significant reduction in decibels and considerable praise from the travelling public. Additionally, when soundwalls have already been constructed and traffic noise is still an issue in neighbourhoods nearby, pavement resurfacing can provide a solution instead of rebuilding or extending the height of soundwalls which can be cost prohibitive.

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