Draft Report April 22, 2004

Rubber Pavements Association

RPA Project # 2003-1

Asphalt-Rubber Noise Data Compilation

(Synthesis of current practices)

by

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Executive Summary

Noise is defined as a loud sound of any sort that is disagreeable or unwanted. Through the ages of civilized history noise has been an annoying irritant to mankind. The Roman Emperor Caesar decreed in 20 BC that carts could only move through the city of Rome during the night, since their noisy din during the day interfered with the daily business of Rome. Carts moving through Rome at night were acceptable since Caesar and his court lived in the mountains far from the noise of the carts in the city. As the centuries past by mankind has tried to live in a peaceful world. Horse drawn wagons and coaches with wooden wheels and iron rims generated plenty of noise in the 1800’s. In the late 1800’s in England road builders used wood blocks and even rubber blocks to deaden the wagon wheel noise. In the 1900’s with the advent of automobiles and rubber pneumatic tires it appeared the tire/pavement noise had finally ended for all time. However, as more automobiles and trucks took to the highways, freeway noise gradually crept back into the city.

Phoenix, Arizona and its surrounding suburban sister cities have experienced a tremendous growth in population in the last 50 years. Phoenix is one of fastest growing cities in all of the country and now is the sixth largest city in population in the United States. With growth in population has come the growth in automobile traffic and the need for more freeways in the Phoenix Metropolitan area. In 1985 the citizens of Maricopa County, which includes Phoenix and numerous sister cities, voted in favor of a 0.5 cents sales tax to fund the design and construction of over 115 miles of new freeways. Since the funding only addressed design and construction of the freeways and not maintenance or rehabilitation it was decided that the freeways would be built with concrete pavements.

Starting in 1986 construction of the freeways began and with time more miles were completed and more people bought homes built near the freeway, and they began to notice the annoying noise of the freeways. Even though sound walls were constructed to mitigate the noise, complaints about noise continued. In the year 2000 the Arizona Department of Transportation (ADOT) began construction of the widening of 10 miles of Superstition Freeway which is in the Phoenix Metropolitan area. The freeway construction included widening the concrete pavement from three lanes to six lanes in each direction to accommodate the over 150,000 vehicles a day that use the freeway, Figure 1. As part of this major construction ADOT decided to overlay all the lanes full width with an asphalt rubber open graded friction course (ARFC). The ARFC surface was selected to provide a new surface with a smooth ride, good skid resistance, a new surface that could be plainly re-stripped and to reduce the tire/pavement noise.
As construction drew to a close and the placement of the ARFC progressed to its ultimate completion drivers, passengers and people living next to the freeway began to notice the new ARFC riding surface was very quiet. Unexpectedly, people began to write the local newspapers and call local radio talk shows in praise of the new quiet riding surface. Although the quiet riding surface was an ARFC it soon began to be called by the local media and people in general simply rubberized asphalt. From this grassroots reaction to peace in the valley, that is the Phoenix Metropolitan area is called the Valley of the Sun, action groups sprang up to petition government to cover all the freeway miles with rubberized asphalt. The local governments as well as state government heard the voice of the people and developed a Quiet Pavements Program in December 2002. Then Governor Jane D. Hull and ADOT Director Victor Mendez informed the public that over the next three to four years ADOT in cooperation the Maricopa Association of Governments (MAG) would overlay the concrete freeway system with rubberized asphalt. The cost of this Program was estimated to be 34 million dollars and it was considered a Quality of Life issue for the people of the Phoenix Metropolitan area.

In addition ADOT would work with the Federal Highway Administration (FHWA) to collect before and after the ARFC overlay noise measurements. This research effort would be used to determine whether the pavement surface noise reducing properties of ARFC would remain at a beneficial level over time. If results of the
study are satisfactory, they could be mathematically modeled and become part of the FHWA National Noise Model. Presently, the FHWA noise model does not allow the surface noise characteristics to be used as an input into the model. Practically speaking, the national noise model only allows walls or berms to be used as a means of reducing noise.

The significant reduction of the tire/pavement noise due to the use of an ARFC and the positive way in which people responded to this triggered the Rubber Pavements Association (RPA) to sponsor this Noise Synthesis Study. The purpose of the study is to acquaint people with what tire/pavement noise is and how an ARFC reduces the noise and to what degree it reduces the noise. Tire/pavement noise has been known about for many years. This report contains a summary of 47 studies based on research and data from the US, France, Portugal, Spain, Sweden, Australia, New Zealand and Japan.

Early studies of noise focused mostly on concrete pavements and some asphalt pavements were used as the basis for developing the FHWA noise policy in 1976. Although much research has continued into tire/pavement research since 1976 the FHWA Policy has remained virtually the same over all these years. Starting in the 1990’s both California and Arizona began to investigate tire/pavement noise and to begin documenting their findings from actual field measurements. These early projects clearly showed that an ARFC surface measurably reduces noise. What these analytical studies did not show is to what degree people would positively react to reducing freeway tire/pavement noise and how passionate they are about this being a quality of life issue.

Noise is measured in decibels and the larger the decibel value the more irritating the noise. Decibels are commonly abbreviated as dB or dBA. The dB abbreviation refers the level of measured noise, whereas the dBA abbreviation refers to not only the measured value but how people respond to the noise. Normal conversation in an office setting is typically about 40-50 dBA. The noise of a lawnmower is generally about 70-100 dBA depending upon how close you are to it and of a diesel truck can be as much as 90 or more dBA. With regard to highways the FHWA National Noise Policy sets an acceptable level of noise at 67 dBA at a distance of 50 feet away from the centerline of the highway. By contrast the Arizona DOT sets its acceptable level of highway noise at 64 dBA also 50 feet from the centerline of the highway. Figure 1 shows common source of noise and the associated noise level.
Highway noise is primarily generated from three point sources, the exhaust or tailpipe noise, the engine noise and the tire/pavement noise. In addition highway noise is also a function of traffic, more cars and trucks, more noise. Automotive engineers have very successfully addressed both tailpipe noise and engine noise by muffling or dampening at the point source. The tire/pavement noise has remained as a somewhat uncontrolled noise source, primarily because the greatest emphasis has been placed on tire/pavement wet weather friction, rather than noise.

Each of the three sources of noise contributes to the total noise. Typically when cars and trucks reach a speed greater than about 35 miles an hour the tire/pavement noise begins to become the dominant source of noise. At normal freeway speeds of 55 miles per hour or greater the tire/pavement interface noise can represent at least 70 percent of the total noise. Significantly reducing the tire/pavement point source of noise obviously can reduce the overall noise significantly as well.
Figure 2 - The source of most highway noise is generated at the tire/pavement interface (Courtesy of ACB Engineering)

What creates the tire/pavement noise is of much conjecture and theory. The most commonly held theory is as the tire passes over the pavement a change in pressure occurs at the tire/pavement interface and this pressure change generates the noise. Another theory holds that the friction or rubbing of the tire against the pavement creates a noise from the rubbing action. Also it has been observed that rolling a wheel across a concrete surface creates more noise than rolling the same wheel across a carpet or rubber mat and thus the softness or stiffness of the pavement itself may amplify or muffle the noise.

Reviewing the three theories about what creates the tire/pavement noise it is possible to postulate why an ARFC would provide a very quiet ride. Empirical measurements demonstrate that as the concrete grooves or air pockets are cut or positioned differently in relation to the tire more or less noise develops. Likewise an asphalt open grade friction course surface has a tremendous amount of air pockets which can dampen the pressure change gradient, thus reducing the noise. An ARFC also has a huge amount of air pockets or air voids, which can contribute to less of a pressure change. The ARFC surface is a much smoother riding surface than the concrete. The ride is smoother because the ARFC mix is placed in a continuous manner with minimal joints and the aggregate top size is 3/8 inch. Such a smooth riding surface and small top size aggregate could contribute to less tire deformation with travel and less squeezing of air between the tire and pavement (less pressure change) and thus less noise.
In addition the ARFC is a rubber like soft surface much like a carpet or rubber mat and this too could reduce noise. The softness of the ARFC comes from a much higher asphalt binder content. Typical open graded friction course mixes have about six percent asphalt, whereas an ARFC has 9 to 10 percent asphalt rubber binder. Rubber is commonly used to reduce noise, thus there may be reason to believe that rubber particles in the ARFC may very well contribute to less noise. All of these material related aspects of an ARFC surface would tend to reduce noise and most likely collectively do contribute to less noise. Thus there is good reason to believe that the empirical evidence of less noise with an ARFC surface is related to a yet not fully understood scientific mechanism.

Although the scientific mechanism of tire/pavement noise phenomenon may not be altogether clear, clearly some surfaces are less noisy than others. Concrete freeway surfaces can be textured or ground to give different levels of noise. All the studies appear to agree that transverse tined concrete is the noisiest surface. Longitudinally textured concrete is somewhat less noisy and a very specially diamond ground surface referred to by the industry as whisper concrete, is the least noisy of any of the concrete surface textures. An ARFC surface is even quieter that any of the concrete textures as seen in the Table 1.

In this Table developed by the Arizona DOT on concrete surfaces and ARFC pavements tested on the Phoenix Metropolitan Freeway system it is clear that the ARFC tire/pavement noise point source level is quietest as shown in the CPX column. The CPX column show actual close proximity noise measurements taken very close to the tire/pavement interface. The 50 feet from centerline noise values are estimated from research conducted by the California Department of Transportation that relates a tire/pavement point source measurement to the standard 50 feet from pavement centerline measurement which is used in the FHWA National Noise Policy. The ARFC is the least noisy surface or quietest pavement surface in this study. For each dB reduction in noise, whether at the tire or farther away a noise wall height can be reduced approximately two feet.

Clearly as shown in Table 1 the ARFC is less noisy in absolute terms but beyond this, there is the second part of the story. When an ARFC is placed over a concrete freeway section the noise level reduction to the human ear seems even more dramatic. From noise testing done by the Arizona DOT and California DOT it was possible to record the noise spectrum over a wide range of frequencies.
Table 1 CPX Noise Measurements at the tire/pavement interface and estimated noise 50 feet away from tire.

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>CPX Noise</th>
<th>Noise 50 Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Trans</td>
<td>104.9</td>
<td>81.1</td>
</tr>
<tr>
<td>Transverse</td>
<td>102.5</td>
<td>78.7</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>99.1</td>
<td>75.3</td>
</tr>
<tr>
<td>Whisper Grind</td>
<td>95.5</td>
<td>71.7</td>
</tr>
<tr>
<td>ARFC</td>
<td>91.8</td>
<td>68</td>
</tr>
</tbody>
</table>

Arizona 101 Wayside Data at 50 ft - Pre & Post Project OGFC
Uncorrected for Traffic Volume/Speed/Mix

Figure 3 - Noise reductions in the 1,000 to 2,000 Hz range due to an ARFC surface (Scofield, 2003)

The human ear can hear sounds from about 500 Hz to about 20,000 Hz. Sounds in the 1,000 to 2,000 Hz range tend to be of an annoying type to the human ear. By recording the frequency spectrum of the concrete pavements it was observed that transverse textured concrete has a tonal spike in the 1,000 to 2,000 Hz range that is particularly annoying to human hearing as shown in Figure 3. The longitudinal and whisper texture concrete has less of a spike, however the ARFC
actually has a dip in the 1,000 to 2,000 Hz range which means to human hearing there is very much less annoying noise being heard. In effect the ARFC is both reducing the overall noise over all frequencies and the irritating tonal spike noise in the 1,000 to 2,000 Hz range.

Figure 4 - Comparison of the CPX (near the tire) tire/pavement noise for different surfaces (Donovan, 2003)

As further documentation of an Open Graded Asphalt Rubber Friction Course noise tests from many different surfaces was compared and combined into a single illustration, shown in Figure 4. As can be seen the least noisy surface measured to date is an Open Graded Asphalt Rubber Friction Course (ARFC). The Open Graded Asphalt Rubber Friction Course (ARFC) produces less noise as documented in numerous reports and by literally millions of people driving over the freeway pavement surfaces in the Phoenix Metropolitan area or living next to a freeway overlaid with an ARFC. The ARFC is less noisy because it contains air pockets, air voids that reduce the pressure change. Also, because of its very smooth riding due to the small aggregate size and because it is a layer of soft material due to the high percentage of asphalt binder and crumb rubber. The Arizona DOT expects at least a 4-decibel reduction with the use of an ARFC and
this reduction has led to a significant improvement in the quality of life of home owners living near the freeway and people driving on the freeway.

From the compilation of the data and analysis of the data obtained in the study the following conclusions can be derived:

- Roadside measurements have shown that asphalt rubber friction courses can achieve 3 to 5 dB noise level reduction when compared to traditional asphalt dense graded surfaces and 6 to 12 dB noise level reduction when compared to concrete surfaces.

- Sound intensity measurements (CPX) have shown that asphalt rubber surfaces are effective in reducing noise by 4 to 6 dB compared with traditional dense graded asphalt concrete and by 6 to 12 dB when compared to concrete surfaces.

Undoubtedly more research will continue to find even better and quieter pavements, but for now an ARFC surface has set the standard for quiet pavements.
Chapter 1 - Introduction

1.1- Background

The increase in interest in noise pollution presents an opportunity to explore alternative methods of noise abatement – an issue that has become paramount throughout the United States and elsewhere. Traditionally, in residential areas where noise from traffic is a major concern, politically or otherwise, sound walls have been used with varying degrees of success. Oftentimes, the positive environmental impact in terms of partially isolating residences from freeway or highway noise through the use of sound walls is negatively offset by the visual impact of such a wall, not to mention the relatively high costs of constructing and maintaining sound walls. Since a large percentage of “freeway noise” emanates from the tire-pavement interface, it is desirable to reduce this share of freeway noise as much as possible.

1.2 - Project Objectives and Scope

The objective of this research synthesis is to collect and compile the existing Asphalt-Rubber noise abatement studies. In addition to examine and list comparable studies and prepare a single document that as best as possible objectively considers the many factors contributing to noise reduction. The major emphasis is focused primarily on the use of gap-graded or open-graded Asphalt Rubber mixes compared to other pavement surface types, in relation to various factors and variables such as:

- Binder content, mixes with different binder contents
- Percent rubber in the binder, mixes with different rubber percentages in the binder
- Aggregate gradation, mixes with various aggregate gradations
- Pavement surfaces, new and old and effect of surface changes with age
- Surface texture (particularly for PCC comparisons)
- Distance from source of noise measurement
- Method of noise measurement
- Traffic mix

All of these various factors to a lesser or greater degree contribute to how noisy the highway will be perceived by the motorist, property owners next to the highway and the general public. It is interesting to note that the present National Noise Policy (Appendix A) as well as individual state policies focus on property owners along and next to the highway. If a highway or freeway is noisy to the motorist inside their vehicle that is of no bearing on the policy. Likewise, the general public, non-property owners also have no standing in terms of the policy. Thus, if walls are built on both sides of a freeway to protect the property owners...
and the noise on the freeway is increased in terms of the driver or passenger discomfort that is of not given any consideration in the National Noise Policy. Could such noise amplification on the freeway contribute to road rage? This is a very valid question and probably needs researching. It is interesting to note that much of the more current noise studies measure the noise at various points including inside the vehicle, fifty feet away from the highway and behind the sound walls, even though only the measurement behind the noise wall is of concern to the Policy. The more advanced noise research is actually measuring the noise at the tire/pavement interface, because it is where so much of the noise comes from. In the Chapter 4 Summary of Research, it can be seen that as the years pass the noise research community becomes more convinced that reducing noise at the tire/pavement interface is the most beneficial to reducing noise overall.

1.3 - About noise

Noise is defined by Webster’s College Dictionary (Web, 2000) as “sound, especially of a loud, harsh, or confused kind” and it is generally considered a nuisance and if too loud a health problem. The annoyance of noise from wheeled vehicles increased as civilization took root and large cities with major commerce emerged. Thus in the modern civilized orderly world of ancient Rome, some two thousand years ago Romans complained about the noise of chariots rattling through their streets. At that time the Roman author wrote “the noise on the streets at night sounded as if the whole of Rome was traveling through my bedroom” (Embleton, 1977). To help address this problem Julius Caesar promulgated a Roman noise ordinance in 44 BC. The ordinance read, “Hence-forward, no wheeled vehicles whatsoever will be allowed within the precincts of the city, from sunrise until the hour before dusk… Those which shall have entered during the night, and are still within the city at dawn, must halt and stand empty until the appointed hour” (Schafer, 1994). Caesar and his court worked in the city of Rome during the day and thus wanted it to be quiet during their deliberations. Before dark Caesar and his court retired to their mountain homes and were far away from the wheeled cart traffic that created noise in the night time hours. It is not known what the penalty for non-compliance was, however it should be recalled that Caesar was not of an easy going nature.

As the centuries quickly passed by, and bypassing the Dark Ages when noise issues took a back seat to merely staying alive, no real changes occurred in the attitude about noise until the late 1800’s when horse cart noise again became an annoyance. In England wooden and rubber blocks were tried as road building materials to quiet the noise from wooden wheels with iron rims (Crocker, 1984). Starting in the 1900’s, carts, wagons and carriages with wooden wheels and iron rims gave way to the automobile with rubber tires. Although rubber tires are much quieter than wooden wheels, the annoyance of so many automobiles, cars and trucks driving the streets lead to new noise issues. Most of these early noise
issues were related to the muffler noise. In the 1930’s the Noise Commission of New York City recommended that the public be aware of muffler noise and purchase silent cars, vehicles that would minimize noise (Bijsterveld, 2001). Later in 1954 the US Automobile Manufactures Association established a voluntary exhaust noise limit equivalent to 84 dBA for their products (Close, 2001).

In 1967 California established more comprehensive noise laws which were copied by many states. Following California’s initiative, the US Federal government passed into law the 1972 Noise Control Act. This act stated that, “although primary responsibility for control of noise rests with state and local governments, Federal action is essential to deal with major noise issues in commerce, control of which require national uniformity in treatment.”

The 1972 Act was further enhanced by a Federal Highways Administration (FHWA) memorandum in 1995 which specifically applied the noise policy to the role played by the tire pavement interaction. The following is quoted from that memorandum (Hibbs, 1996), “On June 12, 1995, the FHWA reissued existing guidance on “Highway Noise Policy and Guidance” with Mr. Kane’s memorandum to Regional Administrators. Of major importance for this effort are the following conclusions regarding pavements (paraphrased from page 38):

- Tire/pavement noise varies with pavement surface type and texture, type of tires, number of trucks in the traffic stream, and vehicle speeds.

- It is difficult to forecast pavement surface condition into the future, and unless definite knowledge is available on pavement type and condition and its noise generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels.

- The use of specific pavement types or surface textures must not be considered as a noise abatement measure.

Practically speaking, this noise policy, notwithstanding substantial research into the measurement of tire pavement noise, in effect meant that only sound walls could be used to abate freeway noise.

Notwithstanding the 1995 FHWA noise policy, many states and researchers continued to investigate tire/pavement surface noise because the citizens in urban areas were complaining more and more about noisy freeways and to the unsightliness of walls. Highway agencies were also concerned about this policy since walls are expensive, noise patterns change creating a need to raise walls, and walls do not always provide enough total noise reduction unless they are extremely tall. In addition due structural inadequacies it may not be possible to raise a wall, thus extra costs are inquired in replacing existing walls. Considerable research was begun in both Arizona and California to investigate how much the noise could be reduced by the use of a quiet pavement surface layer.
While all this research was being conducted, the Arizona DOT in the year 2000 began the widening and re-constructing a major Freeway in the Phoenix Metropolitan area, called the Superstition Freeway project. The Superstition Freeway project was completed in 2002 and consisted of a ten mile long widening of the freeway to six lanes in each direction with concrete. Placed atop the concrete pavement was a one inch (25 mm) thick overlay with an open graded friction course having an asphalt rubber binder. Some of the reasons for the overlay were to create a smooth riding surface, uniformly re-stripe the new six lane freeway, provide good wet weather friction, reduce splash and spray during rain storms and reduce noise in conjunction with the re-building of existing noise walls.

The open graded asphalt rubber mix is commonly referred to as an asphalt rubber friction course (ARFC). The Superstition Freeway has over 150,000 vehicles traveling through the suburban communities of Mesa and Tempe (Figure 1.1). Mesa and Tempe are part of the greater metropolitan Phoenix area comprising the sixth largest population in the United States of over 2.5 million people (Brittanica, 2004). The sound or noise generated by all this traffic roaring back and forth to and from work, and other activities was very annoying, not only to the people who live in Mesa and Tempe, but also the motorists who paid for the freeway. After the ARFC was placed, the noise reduced so significantly that people from all over greater Phoenix metropolitan area began to drive over the new freeway surface just to experience the quiet ride.

Figure 1.1- US 60 Superstition Freeway (Courtesy of Arizona DOT)

Noise measurements indicated a remarkable reduction on the order of 5-10 decibels. In late 2002 the Governor of Arizona, Jane D. Hull, in cooperation with
the Maricopa Association of Government (MAG) and the ADOT, listened to the voice of the citizens of the greater Phoenix area, and notwithstanding federal noise policy developed the Quiet Pavements Program (Appendix B). It should be noted that citizen groups, mayors, city councils, newspapers, local radio and television stations all weighed in on the discussion of freeway noise (Appendix C). Quite honestly the citizens of the Phoenix metropolitan area were not impressed in the least by the national policy where the pavement surface noise was not considered. Over and over again they told the city, county and state government they wanted quieter freeways, and if an asphalt rubber surface provided a significant reduction in noise it should be used. Although technically it may be called an asphalt rubber friction course, the common journalistic reporting terminology was and is rubberized asphalt.

The Arizona Quiet Pavements program will cover the approximately 115 miles of concrete pavement with the much quieter ARFC surface over the next three to four years. The goal of this work is to reduce the noise an average of four decibels. The decision by the Arizona government and more specifically by the Arizona Department of Transportation (ADOT) to commit to reducing (abating) noise by means of using a specific type of pavement surface is contrary to the stated FHWA national policy and has caused considerable discussions. Arizona, along with California has agreed to participate in a study with the FHWA to examine the long-term noise reduction from the use of an ARFC pavement surface. Ultimately, this long-term study may lead to a change in national policy.

This remarkable reduction in traffic noise by the use of ARFC, prompted the Rubber Pavements Association (RPA) to sponsor this research synthesis project. The aim of the report is to synthesize the body of literature on highway noise and express this information in both a narrative and reference format. The intention of the report is to inform the reader not only of just what has been researched in the tire/pavement noise arena but what the research means. Since the whole area of tire/pavement research is new and changing at a very rapid pace much of the emphasis of this report is based on very current research studies completed since 1990. These newer studies shed light on the rationale, mechanism and quantity of noise reduction due to asphalt rubber mixes. Based on many localized or case studies, in Arizona and California, it is well known that asphalt rubber surfaces (both gap- and open-graded) generally reduce tire-pavement interface noise levels by measurable and significant amounts (Gruner, 1990), (Henderson, 1996) and (Bollard, 1995). Research is needed to collect the existing localized data and compile the data to better document the overall benefits of using asphalt-rubber pavement surfaces as a viable and cost-effective noise pollution abatement technique.

To fully understand the myriad of research reports and papers that have been written about the subject of the highway noise, it is necessary to know what noise is and how it is measured. Chapter 2 is a primer on the subject of noise and in particular tire and pavement noise. Chapter 3 discusses the various ways that the tire/pavement interface noise is measured. Chapter 4 is a narrative summary
of many of the most significant tire/noise research projects and their findings and/or conclusions. The intent of this Chapter is to concisely inform the reader of many of the most important and timely research reports that measure and explain the tire/noise with regard to both concrete and asphalt rubber surfaces. Chapter 5 contains a brief discussion on what may be causing noise reduction on asphalt rubber pavements and Chapter 6 contains a Summary of the overall report.
Chapter 2 - What is noise?

2.1 – Noise

Noise is defined as sound or a sound that is loud, disagreeable, or unwanted (Webster, 2002). Noise pollution is annoying or harmful environmental noise. So what is sound and what is the disagreeable, or unwanted sound that we call noise?

Noise comes from how loud something sounds and how disagreeable it sounds. Sound is a vibratory disturbance in the pressure and density of air capable of being detected by the organs of hearing, i.e. the human ear (Webster, 2002). Technically, sound is a variation of density in the air, which propagates at a speed of about 340 meters per second. It is a longitudinal wave motion that, in many ways, may be illustrated by the pressure disturbance, which is called sound pressure around the normal static atmospheric air pressure. Sound pressure, \( p \), is expressed in the unit of Pascal - Pa. The convention in sound is to convert the sound pressure unit into a relative and logarithm scale as shown by the following:

\[
L_p = 10 \times \lg \left( \frac{p}{p_{\text{ref}}} \right)^2
\]

Where,

- \( L_p \) is sound pressure level, expressed as a decibel unit, or dB
- \( p \) is the sound pressure, expressed in Pascal unit, or Pa
- \( p_{\text{ref}} \) is an internationally standardized reference sound pressure of 20 * 10^-6 Pa

However, agreeable and disagreeable sound pressure is a function of frequency and human hearing is not equally sensitive to sound pressure at all frequencies. In particular, human hearing is not very sensitive to low frequency sound. For example, if \( L_p \) for a sound pressure at 100 Hz is 100 dB, and \( L_p \) for another sound pressure at 1000 Hz is also 100 dB, the former may appear less noisy to the human ear or cause less discomfort than the latter. Therefore in order to reflect the proper human reaction to sound pressure (a pleasant sound or disagreeable, unwanted noise), a revision is made by modifying \( L_p \) so that it is proportional to what human ears can react to at all frequencies. Such a revision is made by introducing a weighted mathematical function to adjust the original \( L_p \) data. After many tests were conducted and data collected, a revised standard was established, which is ISO 226. The sound pressure level that is revised according to ISO 226 (ISO, 1987) is denoted not by dB but dBA. Table 2.1 and Figure 2.1 show typical Noise levels from various sources.
Table 2.1 Typical Noise Levels for Various Sources

<table>
<thead>
<tr>
<th>Noise Source</th>
<th>Decibel Level dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-raid alarm (5m distance), Live Rock Music, Chain Saw</td>
<td>120</td>
</tr>
<tr>
<td>Rick music concert (near stage), Steel Mill, Riveting</td>
<td>110</td>
</tr>
<tr>
<td>Jet Take Off (300 m distance), Lawn Mower, Jack Hammer</td>
<td>100</td>
</tr>
<tr>
<td>Diesel Truck, Food Blender</td>
<td>90</td>
</tr>
<tr>
<td>Garbage Disposal, Dishwasher, Freight Train (15 m distance)</td>
<td>80</td>
</tr>
<tr>
<td>Freeway Traffic (15m distance), Vacuum Cleaner</td>
<td>70</td>
</tr>
<tr>
<td>Normal conversation in Restaurant, Office, Background Music</td>
<td>60</td>
</tr>
<tr>
<td>Quiet Suburb, Conversation at Home</td>
<td>50</td>
</tr>
<tr>
<td>Library</td>
<td>40</td>
</tr>
<tr>
<td>Quiet Rural Area and whispering (1m distance)</td>
<td>30</td>
</tr>
<tr>
<td>Quite bedroom</td>
<td>20</td>
</tr>
<tr>
<td>Rustling leaves</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 2.1 – Rough indication of indoor and outdoor noise level scale
(Courtesy Arizona DOT)
2.2 - Tire Pavement Noise

To better understand why asphalt rubber mixes reduce noise, it is necessary to know about tire pavement noise. What is tire pavement noise? When a vehicle is in motion, friction between the vehicle’s body and the air surrounding the vehicle occurs. Such a friction renders an aerodynamic effect, and noise is generated. This is primarily due to the gradient in the air pressure field induced by the friction. This gradient of the pressure field will propagate to generate noise that can be heard at significant distance.

The second source of noise comes from the contact of grooved tires on pavement surfaces occurring as the vehicle moves across the pavement, this creates a substantial sound pressure field that will generate so-called tire/road (rolling) noise. The third source of noise is the vehicle engine and exhaust systems (including fans) will also contribute to the noise. This is called emission or exhaust stack noise.

The combination of all three types of noise consists of the overall spectrum of traffic noise generated by moving vehicles. The acoustic spectrum of traffic noise is of multiple frequencies. The majority of the spectrum falls within the frequency range of 250 Hz and 5000 Hz, which can be heard by human ear, and can cause great discomfort to humans.
Among those three types, tire/road noise is the most prominent; this is primarily due to the increased speed of vehicles traveling on freeways (Figure 2.2). It has been estimated that traffic noise level can be increased by 9 to 12 dBA, which is quite substantial, when the vehicle’s speed is doubled. Secondly, more heavy vehicles with wide and knobby tires are on the road now, which increase the noise intensity significantly.

At the same time, vehicle engines and exhaust systems have been steadily improved during the last few decades. This means that engines are more fuel efficient and quieter, and emission noise is less audible. The car design has also undergone improvements with much advanced aerodynamic compliance. Therefore, tire/road noise becomes the major source of traffic noise.

Depending on the reference location, traffic noise can be classified as either interior noise or exterior noise. The recipient for the interior noise is the vehicle driver and/or passengers. The recipient for the exterior noise may be those who are standing at a distance from the noise source or in a passing vehicle.

The noise propagation from a road to a recipient is influenced by many factors:
- Variation in atmospheric temperatures and wind speed
- Atmospheric turbulence, wind
- Atmospheric humidity
- Ground and soil acoustic properties
- Height above ground level of road and noise recipient
- Traffic volume, number of vehicles
- Shield effect (noise barrier, ground irregularity, embankments, etc.)
- Sound insulation properties of building facades

The low-frequency tire vibration causes the interior noise when a vehicle’s tires hit the road surface. The vibration becomes noise and then is transmitted by components of the vehicle structures such as the axles and springs. In this case, the tire vibration will be directly influenced by the tire/road interaction. This means not only the tire but also the road surface and the structure below will have the same direct influence on interior noise.

The tire/road noise interaction can be analyzed with respect to its frequency range. Generation of the noise band below approximately 800Hz is the result of the tire hitting the pavement, or tangential snap. In this case, air flow will be sucked in and then “pumped” out in between the deformed tire treads and road surface, or “trailing edge”, along the tire rotation direction, generating a hissing type of sound. When the noise spectrum is at a higher level than 800 Hz, the major mechanism that contributes the noise generation is called air-resonant radiation which can be described as a Champagne bottle effect, in which air is pressurized first and then diluted.

2.3 – Understanding the multiple frequencies in noise.

Within noise many frequencies are present. It is necessary to understand what energy level exists at each of these frequencies because the human ear is more sensitive at some frequencies and less sensitive at others. Because it is complicated and time consuming to display all frequencies of sound, it has been agreed to associate energy levels at preset intervals of frequency.

The most basic frequency is the octave band, for which the central frequency of each filter band is two times the central frequency of the immediately preceding band. Therefore, 1/3 octave band means a bandwidth of one third of an octave, or approximately 22% of the central frequency of the band. The further division of 1/3 octave band into subdivision is 1/12 octave and subsequently 1/24 octave. Therefore 1/3 octave is much “broader, wider” than 1/24 octave. The narrower the band the more accurate the information will be about the noise composition. After many years of development, the consensus among experts is that the frequency dependence of the noise level be represented by either 1/3 octave band (also called broad band), or 1/24 octave band (also called narrow band). Figure 2.3 shows an example how to go from a time variation of the noise to its frequency content at several octave bands.
A practical example of the importance of having all the information in the noise spectrum is presented below. This example shows a comparison between the noise levels obtained over a concrete pavement and over a pavement covered with an ARFC (Scofield, 2003).

Figure 2.4 shows a 1/3 octave of noise over a concrete pavement. Note that in Figure 2.5 a 1/24 narrow band evaluation can better identify a peak noise value at 1,500 Hz that otherwise is not apparent in a 1/3 octave analysis. It is interesting that in the overlay with a ARFC using the 1/24 octave band analysis (see Figure 2.6) not only the peak at 1,500 Hz does not exist it is clear that at every level of frequency the energy is much less (lower dBA).

These noise spectrum analysis were made using a sensor near the tire (CPX method described later in Chapter 3), conducted at 60 MPH, which indicated that an 11 dBA reduction had occurred at the tire/pavement interface as a result of the ARFC overlay. In addition to the large reduction in overall noise, there was also a secondary and perhaps more dramatic change resulting from the ARFC surface that is discussed in the following paragraphs.
Figure 2.3 – Description of octave bands (Sandberg, 2002)
Figures 2.4 and 2.5 compare the differences between the 1/3 octave analysis and a narrow band analysis (e.g. 1/24 octave) conducted on the uniform-transverse tining prior to overlay placement. It should be noted that in Figure 2.5 there is a very distinct tonal spike evident at approximately 1,500 hz. This spike is not evident in the 1/3 octave analysis (Figure 2.4) that is traditionally used for analysis in the transportation industry.

**Figure 2.4:** SR101 Pre-Overlay Spectrum Plot for 1/3 Octave Analysis for ADOT Uniform-Transverse Tining of PCC Pavement (Scofield, 2003)

**Figure 2.5:** SR101 Pre-Overlay Spectrum Plot for 1/24 Octave Analysis for ADOT Uniform-Transverse Tining of PCC Pavement, (Scofield, 2003)
Figure 2.6: SR101 Post-Overlay Spectrum Plot for Narrow Band Analysis For ARFC, (Scofield, 2003)

The tonal spike that exists produces considerably more human hearing annoyance than its mathematical impact on the overall dBA for the total spectrum. Human hearing finds tonal spikes such as evident in this spectrum particularly bothersome. This type of tonal spike has been found to occur over a range of 1,000 to 1,500 Hz on different segments of the concrete pavement freeway system constructed with the same uniform-transverse tining requirements.

The comparison between the pre-overlay spectrum shown in Figure 2.5 with the post-overlay spectrum in Figure 2.6, shows that the ARFC overlay provides more benefit than represented using the overall average dBA level. In addition Figure 2.6 shows that the ARFC not only eliminates the tonal spikes but it also reduces the sound levels above approximately 800 Hz and it has a significant reduction between 1,000 to 2,000Hz. There is also an appreciable reduction in the sound levels between 300 and 400 Hz.
3.1- Methods of Measuring Noise

The noise measurement instrument, which is most commonly used, is an electro-acoustical device with a microphone that converts sound pressure (a scale value) into an electronic or voltage signal, or vice versa. The instrument has a variety of names such as noise meter, sound meter, or sound level meter. When placed near a sound source, it will display or readout a single number of the corresponding decibel level in dB or dBA. This value is a function of frequency typically it is obtained by averaging the sound pressure over a pre-set frequency band, typically, from a frequency of about 100 Hz to as high as 20,000 Hz.

There are a myriad of such instruments that can be bought for less than $500 but for serious research, more expensive instruments are needed that may cost as much as $10,000 or more. The more sophisticated instruments can record, store and display noise levels at different frequency bands or ranges so that the noise information over several narrow bandwidths can be obtained and displayed. It is typical to have at least 8 frequency bands that discriminate the whole noise spectrum (from a low of 100Hz to as high as 20,000 Hz).

These sophisticated instruments for measuring noise are called acoustic analyzers or acoustic spectrometers. They are no longer a simple handset device but a complicated system (often integrated with a computer), and involve not only more hardware for data acquisition but also software that can do the manipulation of various filtering techniques. The cost for such a sophisticated system can reach as high as $100,000. Such instruments, both simple and sophisticated, have been widely reported being used in various studies on noise research. The research traffic noise measurements are typically taken with these instruments, which are placed normal (perpendicular) to the road or designated pavement test section. The traffic noise level or spectrum is recorded as a test vehicle drives on the road and passes by the instruments. Such measurements are taken along the side of the road at approximately 50 feet from the centerline of the road and are commonly referred to as passby (or wayside) measurements.

Understanding the tire pavement interaction that generates traffic noise is not as easy as it sounds. Simple handheld measurements and passby measurements have represented the means to quantify the level of noise. However, to better understand how the noise is generated, other noise measurements are needed closer to the noise source, i.e. the tire pavement interface. To better understand tire/road noise at the interface and under actual roadway conditions, a number of noise measuring instruments and/or statistical expressions of noise have been developed. There are two relatively new and very innovative instruments and/or associated noise spectrum analysis that are called the “Close-proximity Method” (CPX), and the “Sound intensity method”.

Chapter 3 – How is Noise measured?
The instrument in CPX is housed in an encapsulated trailer, with microphones being installed inside the trailer and placed near the road surface and the tire. The noise absorptive material is attached to the entire inner side of the trailer for the purpose of enabling the microphones to pick up only the noise from tire-road interaction.

The instrument in the second method is a device with two microphone probes placed near to each other and near a tire. Such a device can measure the sound intensity, which is directional and so it is a vector. In theory, by using a two-probe configuration, this method can eliminate other noise sources and record the noise mainly from tire-road surface interaction in the direction of interest.

The main methods to measure noise are the following

A) WAYSIDE MEASUREMENTS

- The Coast-By (CB) method
- The Controlled Pass-by (CPB) method (a variant of the CB method)
- The Statistical Pass-By (SPB) method
- Source Mapping

B) ON-BOARD MEASUREMENTS

- The Close-Proximity (CPX) method (also called Trailer method)
- Sound Intensity Methods

Although the main objective of these methods is to compare the road surface noise-influencing characteristics, they use slightly different approaches. For example, the CPB and SPB methods both intend to show the combined effect of power unit noise, tire/road noise and propagation over the road surface over the nearest 5-10 m (from the microphone). As such they are well suited for investigations of road surface influence on traffic noise. However, the CPX and CB methods do not measure power unit noise at all, and the CPX method takes the sound propagation effect only partly into consideration. Still, they are useful for road surface comparisons. A brief description of the methods follows.

The Coast-By (CB) Method - A test vehicle equipped with test tires is rolling past a road-side microphone with the engine switched off and the transmission disengaged ("coast-by"). The microphone is positioned 7.5 m or 15 m from the center of the test track or road lane in which the vehicle is coasting (see Figures 2.1 and 2.2). The maximum A-weighted noise level is recorded during the coast-by, usually with the time constant "F" (F for "Fast"). It is also common to make a recording of the frequency spectrum (mostly in third-octave bands) at the moment of peak A-weighted noise. The draft international standard is ISO/DIS 13325.
The Controlled Pass-By (CPB) Method—The method is often used to classify both the road surface and the tire influence on noise. The measurement set-up is very similar to that of the Coast-By method but the test vehicle is cruising-by at constant speed with the engine operating at a condition that is normal for that speed. Generally two different vehicles are used with two different sets of tires. In this way the noise measurements are somewhat more representative of actual field conditions.

The Statistical Pass-By By Method (SPB)—The measurement set-up is very similar to that of the Coast-By method but the test vehicle is cruising-by at constant speed with the engine operating at a condition that is normal for that speed. The method uses many vehicles to simulate normal traffic. Thus there is no control over the vehicle speed, and the technical characteristics of the vehicles (most notably information regarding their tires) are not available. The vehicles are classified in a few main classes determined by the size of the vehicles. Only vehicles that can be measured separately from other vehicles can be used; i.e., the noise level at pass-by of the microphone must not be affected by noise from any other vehicle.

If noise from a sufficient number of vehicles is measured, together with the speed of the particular A vehicle, it is possible to determine an "average" noise level representative of that surface, that speed and that vehicle type. The international standard for this method (ISO 11819-1) and the major reported noise indicator is named the SPB index.
Source Mapping - Recently a new acoustical imaging system has been developed and it is a powerful tool that allows calculating an acoustic map at a distance from the source, in order to rank the areas of noise entry. The last innovation relates to the possibility to carry out an acoustic image of moving sources, in other words to characterize the noise of passage of the studied vehicle. A calculation algorithm was developed allowing the determination of the zones of noise of the vehicle while eliminating the disturbances caused by the movement of sources (especially the Doppler effect). In comparison with the conventional beamforming (i.e. for static sources), there is the necessity to know the vehicle kinematics. It should be noted that there is no restriction on the kinematics: constant speed, acceleration and deceleration. An example of the source mapping set-up is shown in Figure 2.3.

The microphone array is positioned parallel with displacement of the car. Here the starting point for triggering the data acquisition is the passage of the front wheels on a mark on the ground. The car speed is constant at 80 km/h (approximately 50 MPH). These elements allow determining the car position at every moment. A loudspeaker is fixed at the rear window to validate the localization and the evaluation of the sound level. The sound level measured with a sonometer is 71 dB at 1 m for the frequency range 1,000 – 5,000 Hz. Figure
2.4 shows an excellent evaluation of the acoustic level at 70 dB for the frequency range 2,500 – 6,000 Hz.

Figure 2.3 – Layout for Source Mapping (after ABC Engineering)

Figure 2.4 – Source Mapping for a vehicle in motion (ACB, 2004)
ON-BOARD MEASUREMENTS

Close Proximity (CPX) method (a.k.a. "The trailer method"). -The pioneers in applications of the sound intensity technique for sound source localization on tires were the team of Donovan and Oswald at General Motors in the USA in 1980 (Donovan, 1980). The National Center for Asphalt Technology (NCAT) has designed and built two CPX noise trailers. The first was built for the Arizona Department of Transportation (ADOT) and was delivered in late January, 2002. This trailer is now being used by ADOT to evaluate a number of pavement surfaces in Arizona. In September, 2002, the second trailer was delivered to NCAT. Figure 2.5 presents a picture of the trailer. This trailer was used to accomplish the work described in this report. The test tire is mounted on a trailer, which is towed by a towing vehicle, Figure 2.6. Close to the test tire, generally within 0.1-0.5 m (4 to 18 inches), one or more microphones are located. The noise level is measured as an average over a certain time interval, usually 4-60 seconds. Most trailers have an enclosure around the microphone and test tire in order to provide screening from wind and traffic noise. Such enclosures are lined on the inside with sound absorbing material. Some trailers may utilize more than one test tire. The method may also utilize especially designed self-powered vehicles that are not of the trailer type. This method is less sensitive to noise generated by other traffic. This equipment is essentially designed for comparing road surfaces. The major noise indicator is a parameter known as the CPXI (the CPX :x).

Figure 2.6 – CPX Trailer

Sound Intensity - The sound intensity measuring hardware consists of a probe (microphone pair) held next to the tire/pavement contact patch by a fixture attached to the wheel studs of the test tire/wheel. The microphone is cabled to
the interior of the vehicle where the signals are simultaneously captured on a recorder, processed by a real time-analyzer, and monitored with headphones as shown on Figure 2.7. Caltrans has used this equipment to measure tire/pavement noise for various research projects.

Figure 2.7 Sound intensity hardware for measuring tire/pavement noise (Donovan, 2003)

The probe is positioned 75mm (3 inches) above the pavement and 100mm (4 inches) away from the tire sidewall. The probe consists of two 25mm (1 inch) diameter, phase matched condenser microphones spaced 16mm (approximately 5/8 inch) apart and fitted with nose cones. In the example shown in Figure 2.8, a G.R.A.S. type 40AI ½" Intensity Microphone Pair, Larson Davis type LD PRM900C microphone preamplifiers, and B&K type UA0386 nose cones are used. Signals from this microphone chain are input to a Larson Davis (LD) type 2900 two-channel analyzer for immediate sound intensity measurement in 1/3-octave bands.

Measurements are made separately at the leading and trailing edges of the tire contact patch and later averaged together on an energy basis to determine the sound intensity for a given tire or pavement. The signals are also recorded on a Sony TCD D-100 two channel DAT recorder for later narrow band analysis and data back up. A modified version of a Larson Davis type WS001 windscreen is used to further reduce low frequency wind noise on the microphone and provides no measurable insertion loss at higher frequencies. The sound intensity apparatus is installed on a 1997 Subaru Outback, which is also used as the standardized vehicle for pass-by method and tire evaluation (Donovan, 2003)
3.2 - Correlations between noise measurements types

All the methods presented thus far have been developed to measure noise levels for different purposes. When they are all combined to measure noise generated by the tire/pavement interaction some correlations are observed as expected. Paul Donovan and Bruce Rymenr presented an example of such correlations. Figure 2.9 show a correlation between on board measurements and way side measurements. The best 1-to-1 linear fit to the data is shown. Figure 2.9 shows an offset of 23.9 dB between the sound pressure and sound intensity. All data points were within +/- 0.5 dB of the best fit line. In the Caltrans procedure, by averaging the leading and trailing edges together, a more complete representation of the sound propagating away from the tire is obtained. In comparing the 1/3-octave band spectra for the two tire types (Figures 4), it was found that the differences measured in the near field are quite similar to those measured at the pass-by position. It was also found that the difference between coast and cruise pass-by levels was less than 0.5 dB at 97 kph (60 MPH).

![Figure 2.8– Detail of dual microphones for Sound Intensity measurements (Donovan, 2003)](image)
Figure 2.9—Relationship between On-Board (Tire/Pavement interface) to Pass-by (Wayside next to highway) noise levels for Coast Condition (Donovan, 2003).

Of great interest are the correlations made between coast and on board measurements using the sound intensity methodology. As it can be observed in Figure 2.10 the correlation is very good. As such, it can be stated that from measurements made using the sound intensity measurements, it is possible to predict the noise levels at several feet away.

Figure 2.10–Relationship between Sound Intensity and Pass-by method at 25 ft (Donovan, 2003).
Table 3.1 - Comparison of Statistical Pass-By methods (SPB) and Close Proximity Methods (Sandberg, 2002)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Wayside Measurements (SPB)</th>
<th>On-Board Measurement (CPX or Sound Intensity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Results representative of actual traffic noise emission</td>
<td>• Easily applicable in most cases</td>
</tr>
<tr>
<td></td>
<td>• Good assessment of road influence for all vehicle types including heavy vehicles</td>
<td>• Inexpensive and fast to use, once the equipment is available</td>
</tr>
<tr>
<td></td>
<td>• Using a representative vehicle composition (may for example be different in Netherlands from North America or Japan) Accurately describes source and propagation effects</td>
<td>• Measures along extended length of road surface</td>
</tr>
<tr>
<td></td>
<td>• Time consumptive measurement procedure</td>
<td>• Applicable under a wide range of conditions (surface must be dry, however)</td>
</tr>
<tr>
<td></td>
<td>• Measures road surface properties only at one location</td>
<td>• Gives an &quot;absolute level&quot;</td>
</tr>
<tr>
<td></td>
<td>• Only applicable within strict conditions (not too high traffic intensity, no reflective objects close to the microphone, &quot;normal&quot; driver behavior)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Stability with time depends on how the noise characteristics of the vehicle fleet develops</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages and Limitations</th>
<th></th>
<th>Application fields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Accurate and representative assessment of acoustic properties of road surfaces, e.g. &quot;type testing&quot; and general evaluation, at sites meeting stringent acoustic requirements</td>
<td>• An approximate assessment of acoustic properties of road surfaces, at a wide range of sites</td>
</tr>
<tr>
<td></td>
<td>• Spot wise check of state of maintenance and condition</td>
<td>• Conformity of production test</td>
</tr>
<tr>
<td></td>
<td>• Research purposes</td>
<td>• Homogeneity check of road surfaces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Check of state of maintenance and condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Check of long-term performance of test tracks (e.g. ISO 10844 tracks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Check of long-term stability of the SPB method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Research purposes</td>
</tr>
</tbody>
</table>

Because noise levels generated at the tire/pavement contact area is affected by: tire type, velocity and pavement surfaces (stiffness, porosity, roughness, micro-texture and macro texture, composition and material type), it is necessary to understand the advantages and disadvantages of using the different methods in the measurement of noise. Table 3.1 summarizes some of the relationships. The major advantages of the different methods in relation to the pavement surfaces are underlined in the table.
Chapter 4 - Summary of Selected Noise Studies

Numerous research reports have been written on the subject of the noise generated by tires driving over pavements. The most comprehensive publication on the overall subject on tire/pavement noise is the book by Ulf Sandberg “Tyre/Road Noise Reference Book, ISBN 91-631-2610-9 (Sandberg, 2002) and www.informex.info.” In addition to this seminal work, much good research about tire/pavement noise, particularly reports that focus on concrete pavements and on the use open graded surfaces, deserve to be recognized. The following highlighted research papers compliment the Sandberg book, and indicate a growing interest in the reduction of noise in the suburban United States. Much of the early work focused on concrete pavements and concrete pavement texture. However, only recently most of the work has included information about noise on asphalt rubber pavements.

The reader should note that the highlighted papers in this summary use many acronyms and names that are somewhat interchangeable. Concrete pavements oftentimes are referred to as Portland Cement Concrete Pavements and abbreviated as PCC or PCCP. Dense graded asphalt pavements may be called asphalt concrete or hot mix asphalt and abbreviated as AC or HMA, respectively. Hot mix pavements constructed with asphalt rubber asphalt binder may be called by many names. The press and some authors often refer to such mixes as rubberized asphalt. Another common name in California is rubberized asphalt concrete or RAC. Such RAC mixes may be open graded (one size aggregate) or coarse graded or dense graded or even gap graded. Other names used in California include asphalt rubber hot mix gap graded (ARHM-GG) and asphalt rubber hot mix open graded (ARHM-OG). Arizona commonly refers to its mixes as asphalt rubber open graded friction course abbreviated AR-OGFC or ARFC. Likewise in Arizona, a gap graded asphalt mix is abbreviated ARAC. For more detailed information in general about asphalt rubber mixes, the reader can view the ADOT website, www.dot.state.az.us/about/materials/pavedsgn/index.htm.

As seen in Chapters 2 and 3, noise is measured in many different ways. It should be noted that tire/pavement noise is measured either very close to the tire/pavement interface or far away. The measurements made close to the tire/pavement interface (source measurements) are generally in the range of 90 to 110 dBA, and those measurements taken inside the vehicle are more typically in the range of 50 to 80 dBA. Noise measurements taken at the roadside or wayside are, generally, in the range of 60 to 90 dBA. While those taken behind sound walls are in the range of 50 to 75 dBA.

The following excerpts and summaries are for the most part presented in a chronological order.
This report evaluates six texture types, clean burlap drag, burlap drag with mortar buildup, transverse nylon light broom and with heavy brooming, and transverse tine texturing at ¼ and ½ inch spacing. The evaluation was in terms of skid resistance, serviceability, and noise. Skid testing was performed one year after construction with an ASTM skid trailer.

The ranking of skid test results was (high to low) ¼ inch tining, ½ inch tining, heavy broom, light broom, burlap with grout, and clean burlap. The ½ inch tine texture showed only a 7 skid number decrease with an increase in speed from 40 to 70 mph. The clean burlap drag decreased 20 skid numbers over this same speed range (40-70 mph). The speed gradient curves for the ½ inch tining were the most desirable.

Noise was measured with “A” scale of a sound meter which was hand held 25 feet from the near side of a vehicle coasting at 50 mph in neutral gear with the engine idling. Noise on the tined surfaces was about 4dBA higher than that measured on the smoothest surface (clean burlap drag).

The texture related noise is of relatively high frequency (1000-2000hz) when compared to other components of traffic noise and attenuation by physical barriers is greater than attenuation of the other traffic noise components.

In general, engine and exhaust noise are responsible for most noise from automobiles to speeds of about 35 mph. At about 50 MPH tire-pavement interaction noises dominate.

The measured noise with a sound meter was taken approximately 15-25 ft. from the pavements edge. They found that noise increases with increasing texture depth, as measured by the sand patch. The transverse texture produced by a fluted float was less noisy than those of equivalent depth produced by brooming.
Transverse tining spaced at ¾ inch center to center were recommended for tangent sections, while longitudinal tining spaced ¾ inch apart in combination with transverse tining spaced 3 inches apart was recommended for curves. The report noted a 1969 Caltrans study on “Effect Of Pavement Grooving on Motorcycle Rideability”.

This study has a very vivid photo comparing the difference of pavement runoff between a longitudinally tined section and transverse and longitudinal combined section. ASTM skid testing with a bald tire indicated the following ranking (from best to worst): Longitudinal tine (19mm spacing) with transverse (38mm spacing) combined, longitudinal tined with 19mm spacing, transverse tine 19mm groove spacing, sprinkled aggregate, washed mortar, transverse tined 38mm groove spacing, longitudinal tining with 19mm groove spacing, dimpled, and burlap. Note these are different test sections that is why the 19mm longitudinal is in several locations.

This study used 2.5dBA as the level that represents a significant change in noise. A sound recording device was used 25ft. from the center of the lane measuring a vehicle traveling at 48 mph, and an inboard device mounted near the driver’s ear of a vehicle traveling at 55 mph, found inconclusive difference between the textures. A frequency analysis did indicate that the transverse tining produced tones in the frequency range of 1000 Hz and greater. These higher frequencies may produce more objectionable noise for an equal intensity level than would the lower noise patterns produced from longitudinal textures. A panel evaluation indicated the longitudinal tining was slightly quieter.

They noted that the ASTM 274-70 treaded tire provided adequate water escape for speeds up to 35 MPH for the very thin film of water applied during the test. They indicated that the bald tire test is the best indicator of the loss of friction on wet applications for the higher speeds.

(California, 1980)-California DOT (Caltrans), APPRAISAL OF ALTERNATIVE METHODS FOR RESTORATION OF PAVEMENT SURFACE TEXTURE: FHWA/CA/T/-80/02, JAN., 1980.

This report covers the methods that have been used to provide surface texture for worn pavements.

For 15 years Caltrans has reduced wet weather accidents by sawing longitudinal grooving. Early grooving projects experienced an 85% reduction while a recent study attributed a 69% reduction in wet weather accidents. Grooving is preferred strategy. Surfacing grinding appears to be acceptable. Cold planning appears satisfactory for AC pavements, but is not acceptable for PCCP due to spalling at the joints.
Seven finishes representing four basic texturing schemes—tining, carpet drag, brooming, and roller grooving. The transverse time was a comb texture spaced at ½ in centers, 1/8 inch wide, 1/8 to 3/16 in deep. Same dimensions for longitudinal texture.

Study found that the ASTM Treaded tire (E501) was far less sensitive to texture changes than the ASTM Smooth tread tire (E254). This was due to the treaded tires excellent drainage ability which compensated for those textures which did not provide adequate drainage.

Smoothness results using the Illinois Roadmeter ranged from a high of 91 in/mile for the artificial turf/transverse tine to a low of 72 in/mile for the longitudinal broom finish. The transverse tine was about 5 in/mile rougher at the time of construction than the longitudinal tine. After 18 months the transverse tining roughness remained the same while the longitudinal became smoother for a net difference of about 7 in/mile.

Noise measurements were made from inside a coasting vehicle. Range of all textures was from 70dB A to 66dBA. Ranking after construction (high-low) was: transverse tine, transverse roller, transverse broom, longitudinal tine, artificial-turf (control), longitudinal broom, artificial-turf/transverse tine combination. After 36 months all textures, except the transverse roller, were within 1 dBA of the control (artificial turf) which was about 64dBA.

A 3 dBA change in sound is barely discernable to the ear; yet this continues a doubling of sound level, correspondingly, humans perceive a doubling of sound when a 10 dBA change occurs. However, this represents a ten fold increase over the reference sound-level.

Friction number speed gradient changes were associated more with changes in micro-texture than with changes in macro-texture.

The study evaluated both near side and far side noise and attempted to relate this to skid properties measured by the ASTM skid trailer and British Pendulum tester.

The skid resistance of a pavement can be measured in accordance with ASTM E274 (skid trailer) and E303 (British pendulum meter). You can use a blank tire (ASTM E524) or a ribbed tire (ASTM E501).
Noise generated by moving vehicles can be categorized as the tire/pavement interface aerodynamic sources, engine, and exhaust. Tire pavement noise is affected by seven sources: vehicle speed, wheel load, inflation pressure, tread pattern, degree of tread wear, tire size and construction, and road surface texture. Near-field testing usually consists of placing a microphone within a trailer near a special wheel located inside an insulated (sound) compartment. Far-field testing generally refers to microphones mounted along side the roadway measuring a passing vehicle in a coast condition with the engine off or idling.


This report provides a limited comparison between longitudinal and transverse texture performance. It is the basis of Caltrans continuing with the more economical longitudinal texturing.

After 8 years of performance both longitudinal and transverse textures are performing satisfactory based on skid resistance values and accident data. Transverse tine texturing offers advantages of improved stopping ability and rapid removal of rainwater from the pavement surface. However, greater tire noise is generated and some engineers believe that the wear rate is higher, especially for chains or studded tires are used. Construction is more complicated and expensive.

Longitudinal texture imparts a tracking effect to the pavement surface by providing resistance to lateral movement. Caltrans has used longitudinal texturing sense 1977. The spacing of grooves is ¾ in center to center, width of groove is 3/32 inch to 1/8 inch, and the depth is a nominal 3/16 inch.

**Acoustic, 1987**-ACOUSTIC CHARACTERISTICS OF ROADWAY SURFACES WA-RD-129.1, September 1987

This study was a pilot study of the way in which tire/road noise changes as the pavement ages and wears. Thirty-one studies are being evaluated bi-annually. These sections include high density PCCP, latex modified PCCP, Class D ACP open graded, Polyester Fiber ACP, Class B ACP, and Plusride.

Asphalt pavements are quieter than PCCP. In the first few years AC pavements get noisier while PCCP appear to remain the same.

**Jofre, 1988**-Carlos Jofre, Rafael Fernandez and Carlos Kraemer, Concrete Pavement Construction in Spain, TRANSPORTATION RESEARCH RECORD 1182, 1988
Spain has used longitudinal texturing ever since the introduction of slip form pavers. They have found excellent skid properties with this texturing and obtain noise levels 2-4 dBA lower than reported by other European countries using transverse texturing of equivalent depth. Most other European countries use transverse texturing. The Spanish pavements typically test at 72.5 to 78 dBA for peak levels.


The authors reported on research in The Netherlands that showed that an Open Graded Rubberized asphalt surface reduced the noise by 3.5 dBA compared to a dense graded asphalt surface and 9 dBA compared to a concrete surface. This was one of the earliest European studies documenting the noise reduction due to an open graded rubberized surface.


This study determined the effects of surface treatments (texture) on roadside noise levels, with emphasis on high speed roads. Three types of surfaces were evaluated: PCCP, Open Graded Asphalt Concrete, AC, cold slurry seal, and a 14mm chip seal.

The surfaces produced a 9.7 dBA variation in noise level between the surface types. The open graded AC was the quietest surface with L10(h) reductions of 3.3 and 6.3 dBA over Hessian Dragged and Shallow grooved PCCP and 5.9 reduction over AC surfaces. The 14mm chip increased noise levels 2dBA over conventional AC surfaces.

Nine pavement surface types were evaluated: PCCP-deep grooved (9.7 dBA) – 10.7 dBA-, PCCP-shallow grooved (6.3 dBA) –4.6 dBA-, PCCP-Hessian Dragged (3.3 dBA) –5.0 dBA-, Open Graded ACFC (0 dBA-control) –0 dBA control-, Dense Graded AC (5.9 DBA) –6.0 dBA-, Cold Slurry Seal (5.1 dBA)-, 6.4 dBA-, Sealflex OGAC (Mobilplas OGAC, 14mm chip seal –7dBA-.

Noise differences between each of the surfaces compared to the OGAC is shown in () above. The traffic noise differences shown above were driven by noise (i.e.- far field noise measurements). Noise levels ranged from 87 dBA for the PCCP-deep groove to about 77 dBA for the OGAC. There is an excellent table and chart which shows this data. The traffic noise levels were obtained in four 15 minute samples using a Bruel and Kjaer Type 4426 Noise Analyser.
The study also looked at vehicle noise. Vehicle noise was determined, again in far field testing, by measuring the noise produced by a single vehicle as it passed by the monitoring point. The comparisons of these levels to the Open Graded AC are shown as above. This is a summary of a literature search intended to compare the noise levels produced by longitudinal and transverse textures on PCCP.

\textbf{(A, 1990)} - \textit{A COMPARISON BETWEEN TRANSVERSE AND LONGITUDINAL GROOVED CONCRETE SURFACES REGARDING TIRE/ROAD NOISE: International tire/road conference 1990-Proceedings, Volume 1.}

The study evaluated the difference between longitudinal and transverse texturing. The evaluation was in terms of noise, both inside and outside the vehicle, and skid as determined with the Mu-meter. The results obtained showed a slight difference between noise emitted on pavements with transverse and longitudinal pavements; transverse slightly higher, although at midrange frequencies the difference is higher. Friction tests showed better results with transverse texture.

Noise emitted from tire/road interface is a result of two sources: tire rubber vibrations and compression and expansion of the entrapped air and water. The first source is responsible for the higher frequency noise levels whereas the second is responsible for the lower frequency noise levels. The vehicle speed and tire/road texture are associated with the medium frequency noise levels.

They performed a one-third octave spectrum analysis and found the following: The tire/road noise is mostly composed of frequencies below 1600 Hz. The highest sound pressure levels are mainly located in the low frequency range for transverse grooves, above 1600 Hz the sound pressure level decay is more pronounced for transverse grooves. The low frequency range the sound pressure levels are higher for longitudinal grooves, for every test speed. This fact may be related to the longitudinal groove wave patterns (associated wavelengths between 0.4m and 0.6m). At medium frequency range transverse grooves cause higher sound pressure levels, the maximum difference being located at the frequency corresponding to the vehicle speed an groove spacing (4cm) 315 Hz for 45km/h, 400hz for 60km/h, 500 Hz for 75km/h and 630 Hz for 90km/h. On the high frequency range (4 kHz to 8 kHz) longitudinal texture causes higher noise levels. Such differences may be related to located tire/road slipping which should be greater on longitudinal grooves due to groove waving/ Tire rubber slipping noise ranges from 500 Hz to 8,000 Hz.

The friction values ranged from about 60 to 65 on longitudinal grooved surfaces, but was as high as 70 for transverse grooved surfaces (at 60 km/h).

Conclusions from this study are that the transverse texture is more suitable. One comment was that the apparent greater slippage with the longitudinal texture that
tire wear may be greater than with transverse textures. The study also concluded that sound levels on both finishes were similar.


This paper compared two measurement methods, the coast-by-method and the trailer method, for measuring road/tire noise.

The results suggest that loud drainage asphalt decrease in noise with time while quiet ones increase.

One of the most important properties of a road surface are the acoustic properties. Since the tire noise dominates over the power train noise for automobiles at speed above approximately 50km/h and trucks above 70km/h, optimization of the road surface with regard to acoustic properties while enhance the struggle against noise pollution. Measurements with the trailer represent an attractive option for measurement of tire/road noise.


This 1990 study recorded from pass by field measurements that a 1988 overlay of a concrete pavement with a one inch asphalt rubber open graded friction course (ARFC) reduced the noise 6.7 decibels. This was the first ADOT sponsored noise measurements documenting the noise reduction from an ARFC placed on top of an older concrete pavement.


This 1990 for the City of Phoenix, Arizona concluded that an asphalt rubber gap graded mix placed in Phoenix in 1989 was 10 decibels quieter than standard chip seal coat surfaces. This was the first City of Phoenix noise study and it was conducted in response to citizen calls noting the asphalt rubber surface was much quieter than the commonly used chip seal coats and other standard dense asphalt hot mixes.

(PIARC, 1991)-PIARC MARRAKECH CONFERENCE SEPTEMBER 1991

Tire-pavement noise is a result of tire vibration and air escaping. A rough surface causes a tire to vibrate and produce sound. A completely smooth surface entraps air between the tire and pavement causing a hissing sound
produced by the escaping air. A finely textured surface without undulations allows the air to escape without causing tire vibration and is therefore the preferred surface type.

There are three methods for measuring tire-road noise; 1) Measuring the noise caused by normal traffic. This is what people are really interested in. However, since traffic noise is a compendium of many factors (speed number and type of vehicles, weather, surroundings, vegetation, etc.) it is difficult and costly to measure it. 2) Measuring the rolling noise of a test vehicle coasting, with engine, off by a microphone. 3) Measuring the noise near a tire mounted in a noise-measuring trailer.

Many concrete pavers used until recently produced transverse or diagonal waves distanced a few cm apart. Modern slip form pavers are fitted with a longitudinal smoother which flattens any transverse waves left. The longitudinal smoother may reduce tire-road noise as measured by the noise-measuring trailer by 2 dBA at 100km/h.

Longitudinal texturing generally produces 2dBA lower values at 100km/h when compared to transverse texturing. The paper has an excellent graph (figure 4), which show the difference between different types of longitudinal textures. It varied as much as 4dBA between he types (all longitudinal). This produces a smooth by quiet ride. One project that used this produced a reduction in the high frequencies (1000 Hz and higher) of 6-10 dBA. This treatment produced a surface 7dBA quieter than an old concrete pavement and 2.5 decibels quieter than a new pavement with longitudinal texturing. It adds about 10% to the cost. The Belgians are using this as well as the Australians.

The Austrians and Belgians use an epoxy and special chippings to produce add on topping which is as quite as porous pavements. This treatment can be added to older pavements.

The paper also discusses the use of porous pavements which are the best noise abatement surface of everything if the porosity is 20% and greater. The Japanese are the principal users of this technology. It is mainly used for sidewalks, parking lots, and low volume roads. The have about 500,000 square meters installed.

The conclusions of this paper have an excellent chart which gives the amount of noise reduction for each of the above discussed treatments as well as the attendant cost.

This report conducted for ADOT documented that an ARFC reduces the noise 4-6 dBA when placed upon a concrete surface. This very comprehensive report has been used as the primary source document for the basis of setting ADOT’s expectation of at least a 4 dBA reduction of noise when an ARFC is placed on a concrete pavement.


This report at its time was the most comprehensive review of surface textures and their relationship to noise and safety performance. An excellent worldwide general overview of findings with regard to how surface textures related to noise and how they perform over time.

One of the major findings currently shapes the national noise model policy. As quoted from the report, “On June 12, 1995, the FHWA reissued existing guidance on “Highway Noise Policy and Guidance” with Mr. Kane’s memorandum to Regional Administrators. Of major importance for this effort are the following conclusions regarding pavements (paraphrased from page 38):

Tire / pavement noise varies with pavement surface type and texture, type of tires, number of trucks in the traffic stream, and vehicle speeds.

It is difficult to forecast pavement surface condition into the future, and unless definite knowledge is available on pavement type and condition and its noise generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels.

The use of specific pavement types or surface textures must not be considered as a noise abatement measure.”


Interior (within the car) and exterior noise and relative pavement texture was successfully measured at 57 test sites in six states; using the same procedures, test vehicle and measurement equipment. The Fast Fourier Transform (FFT) function narrow band analysis was used to analyze both exterior pass-by noise measurements and interior noise measurements. The exterior noise measurements exhibited discrete frequencies similar to those found during the interior noise measurements both using the FFT method.
The ROSAN texture van provided valuable information about texture depth and spacing in both transverse and longitudinal tined PCC pavements. It proved to be a reliable resource to explain texture variations, which impact noise characteristics. Subjective testing with recorded interior noise was rendered credible and is an important criterion to assess pavement textures included in relative noise comparisons.

The following are a few significant conclusions with regard to noise:

Uniform transverse tinning exhibits discrete frequencies that coincide with calculated locations on the sound spectrum based on tine spacing and vehicle speeds. This causes the whine found annoying to most drivers.

Relatively low correlation was found between either exterior or interior noise with texture depth (ROSAN ETD or mean tine depth), texture width or FN40B. This is believed to be due to the great variation in texture depth in all states. This is contrary to the conclusions of Phase 1 of this study. Pavements were all constructed under the same specification for width of times (3 mm or 1/8”). However, those pavements with the widest and deepest transverse tinning (as measured by the ROSAN algorithm) were often among the noisiest. It could be that the ROSAN procedure partially explains the variation in width. Since width of tinning correlates well with depth, it is hard to say which contributes to the pavement noise, but apparently both do (since deeper transverse tinning was also generally wider).

There is little correlation between IRI and noise, and although it may be a factor, this study was inconclusive on the correlation.

The PNLT metric is not suitable for the evaluation of the tire/pavement noise with tonal components.

AC and longitudinal tined PCC pavements exhibit the lowest exterior noise levels. If longitudinal texture is constructed with a 19 mm uniform spacing, experience from other research indicates it can reduce impact on motorcycles and compact vehicles (however, splash and spray has been noted to be greater on longitudinal compared to transverse textured PCC pavement).

The AC pavements, the longitudinal tined, the LTD only, the random skewed PCC pavements, and the European texture exhibit the lowest interior noise levels in that order. However, most of the AC pavements, the LTD only and the European texture did not provide high texture or high friction.

Of the 21 pavements tested subjectively, the random skewed PCC pavements, the AC pavement, the random transverse, the longitudinal and the European texture PCC pavements exhibit the lowest subjective interior noise levels in that order. However, the AC pavement, one of the random transverse PCC
pavements and the European texture had low texture and all but the random transverse, low friction.

The ROSAN texture van verified the great texture variation that existed among all 57-test sections, between different test sections and within any single test section, especially among PCC pavements, where variations of over 100 percent generally exist. Even among AC pavements, variation is as much as 75 percent between the deepest and shallowest depths existing within several meters of pavement. Measurement of texture with a device like ROSAN is essential for noise comparisons to explain noise characteristics for any tire/pavement noise field evaluation.

Colorado's test sections have the greatest ROSAN mean tinning width (even though constructed with the 3 mm specified width) and also had the greatest ROSAN mean texture depth, and were among the noisiest. The ETD ranged from 1.2 to 3.2 mm compared to the FHWA guideline of 0.8 mm minimum average sand patch. This reinforces the hypothesis that as ROSAN mean texture depth and width increase, so do both interior and exterior noise. Yet correlation between noise and texture depth is low as well as between noise and texture width. Texture depth and width are not the only factors to consider in tire pavement noise generation, however. It is undetermined which is the cause of increased noise, tine depth or tine width, although greater tine depth caused greater tine width in most cases width transverse or skewed tinning.

Longitudinally and random skewed tined PCC pavements are among the quietest pavements for both interior and exterior noise. They can be constructed easily, have good subjective ratings, have no prominent discrete frequencies and can provide good friction and texture. The 25 mm random longitudinal (New Wisconsin #8) has low friction (Fn40 bald of 36.6) yet satisfactory texture (ETD of .71 but a low sand patch of 0.5). This cannot be explained except that the 19 mm spacing has more grooves for water film to escape. The 19 mm spacing is the current FHWA and AASHTO guideline that should be followed for construction. In four states with longitudinal pavements, increases in texture depth of between 50 and 250 percent occurred between test sections, yet only modest or no increase in exterior noise occurred (for example, for Colorado 7 and 9).

Random skewed (1:6) textured pavements can be constructed relatively easily, exhibit low interior noise and no discrete frequencies, and have the best subjective ranking. They have higher levels of exterior noise than longitudinal tined PCC and AC pavements, but lower than random transverse PCC pavements. They have good friction and texture.

Random transverse textured pavements are very sensitive to spacing patterns. They can be satisfactory but when spacing tends to be more uniform, discrete frequencies may develop. This can cause objectionable whine. This was the case in 11 of 15 random transverse tined sections in five states. The majority followed the FHWA random spaced guidelines for tinning (developed by WisDOT).
Table 4.1

<table>
<thead>
<tr>
<th>PAVEMENT TEXTURE</th>
<th>NOISE REDUCTIONS</th>
<th>Interior (Leq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random transverse with no whine: (Based on WI R2, R3 &amp; IA 5, all Which have slight frequency apices)</td>
<td>1 to 3 dBA</td>
<td>&lt;1 dBA</td>
</tr>
<tr>
<td>Random skew, 1:6 (Based on NW5)</td>
<td>4 dBA</td>
<td>1.5 to 2 dBA</td>
</tr>
<tr>
<td>Longitudinal (Based on IA3, IA4, NW8)</td>
<td>4 to 7 dBA</td>
<td>2 dBA</td>
</tr>
<tr>
<td>Opened textured AC (Based on WI I43-4, SMA)</td>
<td>5 dBA</td>
<td>2-3 dBA</td>
</tr>
</tbody>
</table>

Spectral analysis can be a useful tool in further research of acoustical qualities of pavements before their construction. The tool was used to design rake tine spacing and this rake was used to tine two additional test sections in Wisconsin. No discrete frequency due to tire/pavement noise was discovered in objective noise measurements, and no whine was detected by subjective observations of pavement engineers and the researchers. Objective noise levels were lower than similarly textured test sections built in Wisconsin in 1997, but no texture measurements were taken, so the comparison is not valid. As-built measurements of the tine spacing were used to analyze the power spectrum. It showed a low max/min ratio of 1.48, close to the theoretical best rake. Similar rake spacing was used in the construction of pavements in Iowa and Michigan, but the research team did not observe these at the time of this report.

The ground PCC pavement, although not as quiet as other PCC pavements, exhibited no predominant frequency or spike (the pavement was built over 20 years ago, but ground in 1993).

A 1998 project comparing before and after (B/A) noise measurements on recently constructed, random transverse tined pavement and a bridge deck in St. Paul, Minnesota showed a noise reduction of 2 to 3 dB (L_{10}) after diamond grinding. Another project in Wisconsin (2000) showed a 3 dBA reduction in exterior noise (L_{max}) after grinding transverse tined PCC pavement. Both eliminated the whine associated with the tinning:

This study added substantial and significant data on noise and texture characteristics of PCC pavements. There is no recognition of noise differences due to surface texture in FHWA noise models at the present time. This is because there is no extensive long-term evidence of changes in noise and texture over time, nor do states specifications guarantee texture or noise thresholds over time. Therefore, benefits to states that select a texture based on lower initial noise (yet adequate friction and texture depth) cannot have this reflected when it comes to using the FHWA noise models to determine the need
for noise barriers on urban freeways. One or the goals of this research is to lead to national guidelines for texture, yet if no benefit accrues in urban areas as it affects noise barriers, there is no incentive to states to standardize, and hence, no incentive to tire manufacturers to standardize tread design.


Surface textures for concrete pavement have evolved over many years because of faster vehicles and increasing traffic volumes. A variety of textures are now available to enhance a pavement's skid resistance properties and provide a safe and quiet riding surface for motorists. Selecting a texture for a concrete pavement requires an understanding of the particular needs and requirements of the facility, and materials, the skid resistance and noise qualities of the available textures to those needs.

Since the late 1970's, the ideal purpose of concrete pavement surface texturing on high-speed highways has been to reduce wet-weather accidents caused by skidding and hydroplaning. (1) While this primary need remains important, in many locations noise generation has also become a significant issue. One drawback to some of the textures that agencies are currently using on highways is objectionable tire-road noise. Fortunately, recent studies (2, 3) have identified the source of tones that make tire-road noise objectionable, and have refined textures to reduce or eliminate these tones.

Over the past 40 years there have been several shifts in the most commonly applied texture on concrete pavement highways. While the most common texture in North America remains transverse tinning, many US agencies that are concerned about optimizing the surface for noise and skid resistance, are adjusting tine dimensions or switching to an alternate texture for high-speed highways (4). For streets and local roads traditional drag-textures remain the ideal choice, while on airports, the Federal Aviation Administration has specific requirements depending upon the use of the pavement.
<table>
<thead>
<tr>
<th>Texture for Fresh Concrete</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burlap Drag</td>
<td>Produced by trailing moistened coarse burlap from a device that allows control of the time and rate of texturing – usually a construction bridge that spans the pavement. Produces 1.5-3 mm (1/16-1/8 in.) deep striations.</td>
</tr>
<tr>
<td>Artificial Turf Drag</td>
<td>Produced by trailing an inverted section of artificial turf from a device that allows control of the time and rate of texturing – usually a construction bridge that spans the pavement. Produces 1.5-3 mm (1/16-1/8 in.) deep striations when using turf with 77,500 blades/m² (7200 blades ft²).</td>
</tr>
<tr>
<td>Transverse Broom</td>
<td>Obtained using either a hand broom or mechanical broom device that lightly drags the stiff bristles across the surface. Produces 1.5-3 mm (1/16-1/8 in.) deep striations.</td>
</tr>
<tr>
<td>Longitudinal Broom</td>
<td>Achieved in similar manner as transverse broom, except that broom is pulled in a line parallel to the pavement centerline.</td>
</tr>
<tr>
<td>Random Transverse Tine (Perpendicular or skewed)</td>
<td>Achieved by a mechanical device equipped with a tinning head (metal rake) that moves across the width of the paving surface-laterally or on a skew. (A hand tool is sufficient on smaller areas.) Optimal dimensions are: random tine spacing to 75-mm (1/2 to 3 in.). 3-6 mm (1/8-1/4 in.) tine depth, and 3 mm (1/8 in.) tine width. (A 1:6 skew provides lowest noise compared to other transverse tine textures.)</td>
</tr>
<tr>
<td>Longitudinal Tine</td>
<td>Achieved in similar manner as transverse tinning, except that tines are pulled in a line parallel to the pavement centerline. Optimal dimensions are: 20-mm (3/4-in.) uniform tine spacing, 3-6 mm (1/8-1/4 in.) tine depth, and 3 mm (1/8 in.) tine width.</td>
</tr>
<tr>
<td>Exposed Aggregate</td>
<td>Occasional European means of applying a set retarder to the new concrete surface, and then washing away surface mortar to expose durable chip-size aggregates. Requires uniformly applying chips to fresh surface and mechanically abrading surface to wash away still-wet mortar.</td>
</tr>
<tr>
<td>Texture for Hardened Concrete</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Diamond Ground</td>
<td>Longitudinal, corduroy-like surface made by equipment using diamond saw blades gang-mounted on a cutting head. The cutting head produces 164-197 grooves/meter (50-60 grooves/foot) and can remove 3-20 mm (1/8-3/4 in.) from the pavement surface.</td>
</tr>
<tr>
<td>Diamond Groove</td>
<td>Grooves sawed into surface longitudinally for highways and transversely for airports. Made by same equipment for diamond grinding. Typically, the grooves are 6 mm (1/4 in.) deep, 3 mm (1/8 in.) wide and spaced 20 mm (3/4 in.) apart. On airports grooves are 6 mm (1/4 in.) wide and spaced 40 mm (1-1/2 in.) apart.</td>
</tr>
<tr>
<td>Abraded (Shot-blasted)</td>
<td>Etched surface produced by equipment that hurls abrasive media within an enclosed housing. The abrasive media impacts the surface and removes a thin layer of mortar and aggregate. The depth of the removal is controllable and the dust is vacuumed into a baghouse.</td>
</tr>
</tbody>
</table>

*For best results, most agencies precede tinning with a burlap or artificial turf drag texture.

The character of any texture divides into two categories: micro-texture and macro-texture. Micro-texture is fine-scale roughness contributed by the fine aggregate (sand) in the concrete mortar. Macro-texture is the measurable, deep striations or grooves formed in the plastic concrete. Macro-texture also may come from grooves cut or sawed into a hardened concrete surface. Textures that create high skid resistance have good quality micro-texture.
## Table 4.3

<table>
<thead>
<tr>
<th>Texture</th>
<th>Subjective Rank</th>
<th>Interior dBA</th>
<th>Exterior dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Transverse Tine – skew 1:6</td>
<td>1</td>
<td>67.6</td>
<td>82.4</td>
</tr>
<tr>
<td>Random Transverse Tine – skew 1:4</td>
<td>2</td>
<td>67.2</td>
<td>83.1</td>
</tr>
<tr>
<td>Asphalt – SHRP</td>
<td>3</td>
<td>65.9</td>
<td>81.1</td>
</tr>
<tr>
<td>Variable Transverse Tine</td>
<td>4</td>
<td>67.7</td>
<td>81.0</td>
</tr>
<tr>
<td>25-mm Uniform Longitudinal Tine</td>
<td>5</td>
<td>68.0</td>
<td>83.9</td>
</tr>
<tr>
<td>Exposed Aggregate</td>
<td>6</td>
<td>67.4</td>
<td>-</td>
</tr>
<tr>
<td>38 mm Random Transverse Tine (MN)</td>
<td>7</td>
<td>66.9</td>
<td>82.6</td>
</tr>
<tr>
<td>Transverse Grooved (13 mm intervals)</td>
<td>8</td>
<td>68.2</td>
<td>83.3</td>
</tr>
<tr>
<td>19 mm Uniform Transverse Tine</td>
<td>9</td>
<td>70.0</td>
<td>83.8</td>
</tr>
<tr>
<td>Diamond Ground PCC</td>
<td>12</td>
<td>69.3</td>
<td>81.2</td>
</tr>
<tr>
<td>25 mm Random Transverse Tine (WI)</td>
<td>15</td>
<td>68.6</td>
<td>83.4</td>
</tr>
<tr>
<td>25 mm Uniform transverse Tine</td>
<td>20</td>
<td>69.6</td>
<td>86.3</td>
</tr>
</tbody>
</table>

Twenty surfaces were included in the subjective testing experiment, including some duplicate textures from various states. 12 sections are included in this table for brevity. (25.4 mm = 1 inch).

Similar results to those found in the Wisconsin study were also found recently in Colorado. As a result, Colorado changed their highway-texturing requirement from a 25-mm (1-in.) uniform transverse tine to 18-mm (3/4-in.) longitudinal tine.

Minnesota also evaluated their surface textures recently. In the metropolitan area surrounding Minneapolis and St. Paul, pavement noise has become an important consideration as roadways there are widened and become closer to the surrounding receptors. Supported by skid and noise data, Minnesota DOT switched to an artificial turf drag texture on all new concrete pavements in 1999. The artificial turf drag texture specified in Minnesota provides skid resistance and noise qualities equivalent to asphalt pavements in the area. The artificial turf drag specification requires a mean texture depth of 1.0 mm (0.04 in.) or more based on the average of 4 sand-patch tests per this specification is to create a smooth tire SN40 of about 32 and a ribbed tire SN40 of about 45.

The mean texture depth is estimated by profiling the pavement surface or measured from the sand patch test. Surface friction is measured using the standard trailer test.

The sand-patch test involves spreading a known volume of material (uniformly graded round glass beads) on a clean and dry pavement surface and measuring the area covered. The material spread on the surface completely fills the surface voids to the tips of the surface aggregate particles. The area covered by the material is related to the surface macro-texture, and the average depth between
the bottom of the pavement surface and the tops of the surface aggregate particles. The average macro-texture depth is determined.


The authors researched the use of the then new March 30, 1998 Federal Highway Administration noise model computer program TNM (Traffic Noise Model), Version 1.0 for predicting noise generated by traffic on Arizona highways. They took noise measurements at 18 different highway locations and reported them in accordance with recognized prescribed testing methods of noise data recording up to a distance of 400 feet from the pavement. These Arizona noise measurements, typically taken 50 feet from the pavement, ranged in value from as low as 45 dBA for an asphalt rubber friction course to as high as 69 dBA for a concrete pavement. The noise measurements were used to develop a state-specific noise database in keeping with the TNM’s nationalized Reference Energy Mean Emission Level (REMEL) database. This Arizona data was also used to test the then current FHWA highway noise analysis programs (STAMINA2.0/OPTIMA).

Essentially the primary issues regarding the author’s research regarded the required implementation of FHWA’s TNM for the Arizona Department of Transportation (ADOT) using the nationalized REMEL in Arizona. A number of states have FHWA approved state-specific REMEL data for STAMINA that have been demonstrated to be more accurate than the 1974 national emission (noise) data. These states are given authority under 23 CFR 772 to determine their own state specific REMEL database. In addition, provisions are contained in the TNM model for different emission level data to be used. Thus the ADOT was trying through this research project to use its own REMEL database in the new TNM.

In conclusion, the research report stated that the results presented in Chapter VIII, Model Validation, presented clear evidence that use of Arizona state-specific REMEL data increases the accuracy of both STAMINA and TNM over the same models using the FHWA/TCS national REMEL data. These results illustrate that for distances up to 400 feet, the STAMINA model using Arizona state-specific REMEL data is the most accurate prediction method for sites in Arizona. It was also demonstrated that TNM using the FHWA/TCS national REMEL data is the least accurate prediction method for the sites in Arizona.

Other conclusions included the following:
*The Arizona TNM REMEL data is different than the FHWA/TSC (TCS is the Volpe National Transportation Systems Center) national TNM REMEL at a 95% confidence level for all three vehicle types addressed in this report.
*Arizona state-specific REMEL data increases the accuracy of both STAMINA and TNM over the same models using the FHWA/TCS national REMEL data, when modeling sites in the state of Arizona.

*The most accurate prediction method for sites in Arizona at distances up to 400 feet from the roadway is the STAMINA model using Arizona state-specific REMEL data.

*The least accurate prediction method for Arizona sites at distances up to 400 feet from the roadway is the TNM model using national REMEL data.

*TNM significantly over-predicts sound levels whether using either FHWA/TCS or Arizona state-specific REMEL data.

(Sandberg, 2001)-Inter Noise 2001- Tire/road noise-Myths and realities,-

Tire road noise is an important part of vehicle noise at speeds above 50 km/h (70 for trucks). Nowadays tire/road noise dominates during almost all types of driving for cars and down to about 40 km/h for trucks (vehicles meeting EU requirements). Manufacturers have done a lot to reduce vehicle and tire road noise in some respects; but yet it seems that vehicle noise sometimes has increased rather than decreased. The speed influence is large but not very interesting. It is shown that there are unexpected relations between speed-related factors and that these can be useful in data presentation.

Different road surfaces may give a large variation in noise levels. The variation is very large, albeit the most common and useful surfaces are close together on the noise scale. Tires variation is large in noise emission as such many tire types should be included in the data set. Winter tires are much more noisy than summer tyres. This is a myth based on the past. Currently, winter tires may be the "quiet" tires. The width of the tire is a very influential factor. A noise-width relation covering the range from "tiny" bicycle tires to large truck tires is presented.

Tire road noise from a heavy truck can emit lower tire/road noise than some cars. Recent results show that there is no tradeoff between low noise emission and high safety; neither with rolling resistance. Calculation exercises are presented that suggests that low-noise tires as well as low-noise road surfaces may be very cost efficient.
This book is the most complete and comprehensive on the subject of tire and road noise, with over 600 pages of facts and figures on the subject. Amongst many relevant sources of information and data for the purpose of this report the most significant one are the results from noise measurements using the CPX method executed over several pavement surfaces as presented in Figure 4.1. Although noise measurements over asphalt rubber surfaces are not included in the data the overall trend of the data is very similar to that presented later in a study by Donovan and Rymer (Donovan, 2003), which contains asphalt rubber pavement surfaces.

It is clear that at the source the noise generated by tire/pavement interactions varies significantly with pavement surface. It is also clear that PCC surfaces generate more noise than asphalt pavements.
Figure 4.1 – Comparison of dB generated over several types of pavements

(Butka, 2002) - M.P. Bucka, ASPHALT RUBBER OVERLAY NOISE STUDY UPDATE, County of Sacramento, AAAI Report 1272, December 2002
This report provides a noise measurement survey over a ten year period in the city of Thousand Oaks, CA on six street sections of asphalt-rubber overlay and two street sections of standard asphalt overlay from 1991 (prior to re-surfacing) to 2002.

It took account of vehicle types (automobiles, medium trucks, and heavy trucks) into an unified value and traffic noise exposure levels vary according to the equivalent numbers of vehicles (Ne) passing by a location. This value is computed from:

\[ Ne = N + 10 \text{Nmt} + 32 \text{Nht} \]

where \( N \) = number of automobiles, 
\( \text{Nmt} \) = number of medium trucks, 
\( \text{Nht} \) = number of heavy trucks.

The algorithms and procedures given in FHWA-RD-77-108 (the FHWA Highway Traffic Noise Prediction Model) were used to normalize the measured sound levels to common traffic flow conditions.

The survey shows that new rubber asphalt overlay can reduce traffic noise exposure levels by as much as 3 to 7 dB A (+ 1.5 dB). The re-surfacing of any street, which was in poor repair, will reduce traffic noise levels. However, the additional noise reduction attributed to asphalt rubber overlay over that obtained by use of standard asphalt is 2 to 5 dBA (+ 1.5 dB).

Also, the asphalt rubber overlay noise reduction was greatest along streets where the tire/pavement noise source is dominant. This is the case where speeds are relatively high, and truck traffic is relatively low.

The survey also shows that after ten years, asphalt rubber overlays have less ability to reduce noise, but the reduction is still detectable between 1 to 3 dBA at locations where auto speeds are relatively high, under free-flowing conditions, and with low percentages of truck traffic.


This analysis concludes that the use of rubberized asphalt on Alta Arden Expressway and Antelope Road in Sacramento County, California resulted in a net decrease in traffic noise levels of approximately 4 dB over that provided by conventional asphalt. These conclusions hold for both the near and long-term conditions from 1992 to 1999, a six-year period of time. These local test results,
when considered with other studies conducted nationally and internationally, support the use of rubberized asphalt as a viable noise mitigation option.

Figure 4.2- Change in noise readings of a dense graded asphalt mix over a four year time period.

Figure 4.3 Noise reduction of an asphalt rubber overlay over a six-year period.
Its use (asphalt rubber mix) could, in some cases, eliminate the need for noise barriers or reduce the heights of the barriers required to achieve satisfaction with local, state and federal noise standards. These local test results, when considered with other studies conducted nationally and internationally, support the use of rubberized asphalt as a viable noise mitigation option.

It should be noted that the effectiveness of rubberized asphalt in reducing traffic noise levels would be highest on roadways with relatively low percentages of heavy duty trucks, as truck engine and exhaust stack noise is not believed to be substantially affected by rubberized paving.

This report also collects some results of using asphalt-rubber in noise reduction in other countries as presented in Table 4.4.

Table 4.4 - Summary of results obtained from studies in several countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Reported Noise level Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>1981</td>
<td>8-10 dB (65-85%)</td>
</tr>
<tr>
<td>Canada</td>
<td>1991</td>
<td>Shown noise reduction</td>
</tr>
<tr>
<td>England</td>
<td>1998</td>
<td>Project not completed</td>
</tr>
<tr>
<td>France</td>
<td>1984</td>
<td>2-3dB/3-5dB (50-75%)</td>
</tr>
<tr>
<td>Germany</td>
<td>1980</td>
<td>3dB (50%)</td>
</tr>
<tr>
<td>Austria</td>
<td>1988</td>
<td>3+ dB</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1988</td>
<td>2.5dB</td>
</tr>
</tbody>
</table>

(Rymer, 2002)-CA SR138 Project, Bruce Rymer, 2002

Noise measurement using both the pass-by method (microphones were placed at 25 feet and 50 feet from the centerline) and the sound intensity method was carried over a five year period on California State Route 138 with 5 test sections, which are: DGAC (30mm), OGAC(30mm), OGAC(75mm), RAC(30mm), and BWC(30mm). Two tire types were used in the pass-by method: Good Year (Aquatred 3) and Michelin, in which Michelin gave rise to lower noise level than what Aquatred 3 did. Five tires were used in the sound intensity method: Good Year (Aquatred 3), Michelin, Uniroyal, Mastercraft, and Firestone, in which the lowest and highest noise level was recorded for Uniroyal brand and Firestone brand respectively.

The results are:
1. Test pavements 1 to 4 dB quieter than reference DGAC across the spectrum of 500 HZ to 5000HZ
2. 75mm OGAC quietest
3. BWC highest level other than DGAC
4. 30mm OGAC and RAC about equal
5. Good agreement between Pass-by & sound intensity
6. Rank order of pavement independent of tires Rank order of tires mostly independent of pavement

(Rymer, 2002)-I-280 in San Mateo County CA, Bruce Rymer, 2002

Comparison between PCC and OGRAC was made on noise along the test section on I-280 in San Mateo County in 2002. The sound intensity method was employed. PCC received both textured and regular grinding. The finding was that OGRAC enjoyed 6 dBA lower noise magnitude than PCC as demonstrated in Figures 4.4 and 4.5.

Figure 4.4 – Overall Sound Intensity Levels function of the 1/3 Octave frequency four types of pavement surfaces on California Highways I-280
There are several noise source location techniques available to engineers working on Noise, Vibration and Harshness (NVH) problems. Choosing the right technique depends on the application. As well as the information required. This article reviews techniques for noise source location and quantification applications. Including the relatively new beam forming method. An innovative beam former microphone array is also presented and compared to traditional array designs and performances.

Modern noise source location techniques are extremely valuable tools in mechanical engineering industries. It is important to understand the acoustic behavior of structures in the auto- motive and aerospace industries. As noise investigations are crucial for regulations and research and development. Furthermore it is important to be able to locate and quantify noise sources with
reliability. Fast and accurate techniques due to the excellent performance of modern computers and advances in acoustics sciences. Many new tools are available that can be used by any NVH engineer.

The article presents a review of the following noise source location techniques:

- Sound pressure mapping.
- Sound intensity and selective intensity.
- Near-field acoustic holography-
- Non-stationary acoustic holography-
- Beam forming (phased array technique),
- Inverse Boundary Element Methods (IBEM).


Using beam forming techniques the authors were able to determine clearly that most of the noise at 160 Km/h (96 mph) is derived by the tire/pavement interaction. Similar studies indicated that identical results are reached even at velocities of 60 mph. It is clear from Figure 4.6 that most of the noise is generated at the tire/pavement interface.

Figure 4.6 - Beam forming (map sourcing) techniques identify noise levels in a moving vehicle at 160 km/h.
Traffic noise is a serious problem. Engine, exhaust, aerodynamic, power train noise and pavement/tire noise contribute to traffic noise. The FHWA Noise Abatement Criteria states that noise abatement must be considered for residential areas when the traffic noise levels approach or exceed 67 dB (A). To accomplish this level, many areas in the United States are building large sound barrier walls at a cost of one to five million dollars per roadway mile. Research in Europe and in the United States has indicated that it is possible to build pavements that will provide low noise roadways. In January of 2002, the National Center for Asphalt Technology initiated a research study with the objective to develop safe, quiet and durable asphalt pavement surfaces. The first step towards accomplishing this objective was to develop a fast and scientifically reliable method for measuring the acoustical characteristics of pavement surfaces.

Two general methods have been developed for measuring pavement noise levels in the field: the statistical bypass approach as defined by International Standards Organization (ISO) Standard 11819-1 and the close proximity method (CPX) as defined by ISO Standard 11819. This methodology utilized the CPX procedure.

Table 4.5 presents the results of the testing. The comparison of the different sections is based on the date at 60 mph data is available at all of the test sections.
Table 4.5 – Noise Data

<table>
<thead>
<tr>
<th>City</th>
<th>Route</th>
<th>Surface Type</th>
<th>Tire</th>
<th>Noise Levels (dB(A))</th>
<th>45 mph</th>
<th>60 mph</th>
<th>70 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lansing</td>
<td>I-96 E</td>
<td>Concrete</td>
<td>Master Craft</td>
<td>97.0</td>
<td>100.8</td>
<td>102.3</td>
<td></td>
</tr>
<tr>
<td>1 Lansing</td>
<td>I-96 E</td>
<td>Concrete</td>
<td>UniRoyal</td>
<td>95.2</td>
<td>98.8</td>
<td>100.8</td>
<td></td>
</tr>
<tr>
<td>1 Lansing</td>
<td>I-96 E</td>
<td>Concrete</td>
<td>UniRoyal</td>
<td>96.0</td>
<td>99.1</td>
<td>100.5</td>
<td></td>
</tr>
<tr>
<td>2 Coldwater</td>
<td>U-69 S</td>
<td>SMA</td>
<td>Master Craft</td>
<td>95.1</td>
<td>98.2</td>
<td>100.2</td>
<td></td>
</tr>
<tr>
<td>2 Coldwater</td>
<td>U-69 S</td>
<td>SMA</td>
<td>UniRoyal</td>
<td>94.0</td>
<td>97.8</td>
<td>98.7</td>
<td></td>
</tr>
<tr>
<td>3 Coldwater</td>
<td>I-69 S</td>
<td>Longitudinal Tined*</td>
<td>Master Craft</td>
<td>97.0</td>
<td>100.5</td>
<td>102.7</td>
<td></td>
</tr>
<tr>
<td>3 Coldwater</td>
<td>I-69 S</td>
<td>Longitudinal Tined*</td>
<td>UniRoyal</td>
<td>95.8</td>
<td>99.9</td>
<td>101.7</td>
<td></td>
</tr>
<tr>
<td>4 Coldwater</td>
<td>I-69 S</td>
<td>Transverse Tined*</td>
<td>Master Craft</td>
<td>97.5</td>
<td>100.6</td>
<td>102.8</td>
<td></td>
</tr>
<tr>
<td>4 Coldwater</td>
<td>I-69 S</td>
<td>Transverse Tined*</td>
<td>UniRoyal</td>
<td>96.8</td>
<td>100.6</td>
<td>102.2</td>
<td></td>
</tr>
<tr>
<td>5 Detroit</td>
<td>I-96 E</td>
<td>Concrete</td>
<td>Master Craft</td>
<td>95.1</td>
<td>99.3</td>
<td>101.1</td>
<td></td>
</tr>
<tr>
<td>5 Detroit</td>
<td>I-96 E</td>
<td>Concrete</td>
<td>UniRoyal</td>
<td>93.8</td>
<td>97.2</td>
<td>99.3</td>
<td></td>
</tr>
<tr>
<td>6 Detroit</td>
<td>I-96 E</td>
<td>SMA</td>
<td>Master Craft</td>
<td>94.4</td>
<td>98.4</td>
<td>100.3</td>
<td></td>
</tr>
<tr>
<td>6 Detroit</td>
<td>I-96 E</td>
<td>SMA</td>
<td>UniRoyal</td>
<td>93.8</td>
<td>96.7</td>
<td>98.5</td>
<td></td>
</tr>
<tr>
<td>7 Detroit</td>
<td>I-96 E</td>
<td>Dense Graded</td>
<td>Master Craft</td>
<td>94.8</td>
<td>98.8</td>
<td>100.6</td>
<td></td>
</tr>
<tr>
<td>7 Detroit</td>
<td>I-96 E</td>
<td>Dense Graded</td>
<td>UniRoyal</td>
<td>94.1</td>
<td>97.2</td>
<td>99.2</td>
<td></td>
</tr>
<tr>
<td>8 Detroit</td>
<td>I-275 N</td>
<td>Superpave</td>
<td>Master Craft</td>
<td>96.1</td>
<td>99.9</td>
<td>101.1</td>
<td></td>
</tr>
<tr>
<td>8 Detroit</td>
<td>I-275 N</td>
<td>Superpave</td>
<td>UniRoyal</td>
<td>95.1</td>
<td>98.7</td>
<td>100.7</td>
<td></td>
</tr>
<tr>
<td>9 Detroit</td>
<td>I-275 N</td>
<td>Concrete</td>
<td>Master Craft</td>
<td>94.6</td>
<td>98.9</td>
<td>100.4</td>
<td></td>
</tr>
<tr>
<td>9 Detroit</td>
<td>I-275 N</td>
<td>Concrete</td>
<td>UniRoyal</td>
<td>93.6</td>
<td>96.6</td>
<td>98.7</td>
<td></td>
</tr>
</tbody>
</table>

* Concrete

Comparison of surfaces

The quietest pavement was the mix in Detroit and the noisiest surface was the transverse tined concrete surface at Coldwater. Three types of pavement were tested: dense-graded asphalt, SMA, and Portland cement concrete. For each pavement section the noise level used for comparison purposes was an average noise level for the two tires. The average noise values for the three surfaces at 60 mph was:

- Stone Matrix Asphalt (SMA) – 97.6 dB(A)
- Dense Graded Asphalt – 98.6 dB(A)
- Portland Cement Concrete – 99.4 dB(A)
For the Portland Cement Concrete surface, the noisiest surface was the transverse tined surface (100.6 dB(A)) and the quietest section was the diamond ground surface (97.7 dB(A)). The diamond grinding of the surface brought the noise level for the concrete pavement down to the average level of a dense graded asphalt pavement.

**Comparison of tires**

The average noise level for all the pavements at 60 mph was 99.0 dB(A). The average noise level for the Master Craft tire was 99.4 dB(A) and for the UniRoyal tire was 97.9 dB(A). This is logical in that the Master Craft tire had the most aggressive tire pattern. Based on the testing conducted in Michigan, it is concluded that the pavement types could be rated as follows with regard to noise levels: SMA < Dense Graded Asphalt < PC


A comparison of two pavement surfaces one with PCC and another with Asphalt rubber (open graded asphalt rubber mix) was made on highway A-7 near Valencia, Spain. The studies were executed using the pass-by method using near to different segments of the freeway. The authors identify that the measurements of the asphalt rubber section were done under circumstances that led to higher velocity of the vehicles. Nevertheless the results presented in Table 4.6 indicate that the noise levels in the asphalt rubber sections were significantly lower than those measured at the PCC section.

**Table 4.6 - Comparison of measurements made in PCC and asphalt Rubber sections.**

<table>
<thead>
<tr>
<th>Type of Vehicle</th>
<th>PCC Level dB(A)</th>
<th>Average Acoustic Pressure</th>
<th>ARFC</th>
<th>Average Acoustic Pressure</th>
<th>Reduction Level dB(A)</th>
<th>% de reduction Acoustic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>101.43</td>
<td>2.35</td>
<td>96.73</td>
<td>1.36</td>
<td>4.70</td>
<td>42</td>
</tr>
<tr>
<td>SUV</td>
<td>103.90</td>
<td>3.12</td>
<td>93.88</td>
<td>0.98</td>
<td>10.02</td>
<td>68</td>
</tr>
<tr>
<td>Light Vans</td>
<td>103.58</td>
<td>3.01</td>
<td>98.41</td>
<td>1.66</td>
<td>5.18</td>
<td>45</td>
</tr>
<tr>
<td>Big Vans</td>
<td>105.87</td>
<td>3.91</td>
<td>101.78</td>
<td>2.44</td>
<td>4.09</td>
<td>38</td>
</tr>
<tr>
<td>Small Treuks</td>
<td>106.44</td>
<td>4.18</td>
<td>102.54</td>
<td>2.67</td>
<td>3.90</td>
<td>36</td>
</tr>
<tr>
<td>Big Trucks</td>
<td>109.86</td>
<td>6.20</td>
<td>100.60</td>
<td>2.13</td>
<td>9.27</td>
<td>66</td>
</tr>
<tr>
<td>Normal Trailer</td>
<td>110.33</td>
<td>6.55</td>
<td>103.36</td>
<td>2.93</td>
<td>6.97</td>
<td>55</td>
</tr>
<tr>
<td>Tank Trailer</td>
<td>109.92</td>
<td>6.24</td>
<td>102.48</td>
<td>2.65</td>
<td>7.44</td>
<td>58</td>
</tr>
</tbody>
</table>

Rolling wheel tire/pavement interface noise is an important part of traffic noise. It is possible to reduce such noise by using suitable road surfaces. This paper presents the basics of low noise surfaces. The evaluation of rolling noise, its importance in the vehicle noise emission is illustrated using both a light and heavy vehicle. The main phenomena in tire road noise namely asphalt mix porosity is well researched. The physical models help to explain the model but statistical models appear more operationally well suited in the short range. 


Road surfaces represent a significant contribution to tire-road noise reduction and consequently to traffic noise reduction. In order to evaluate their performance, a pass-by method is typically used, however due to its limitations, the non-stationary Close Proximity Method was used in France. For this purpose, the French Road Research Laboratories developed a CPX method. The equipment consists of a set of three microphones mounted near the tire.

Figure 4.7 -Variation of noise level over several pavement surfaces at 90Km/h at 20C using the “isolated vehicle method”.

In Figure 4.7 the pavement surfaces are the following:
The different type of pavement surfaces are as translated from French to English by the Author:
BBDr = béton bitumineux drainant-(porous drainage layer)
BBUM = béton bitumineux ultra mince-(very, very thin dense graded AC mix)
BBTM = béton bitumineux trés mince-(very thin dense graded AC mix)
BBM = béton bitumineux mince-(thin dense graded AC mix)
BBSG = béton bitumineux semi grenu-(gap graded AC mix)
ES = enduit superficial-(seal coat/chip seal type layer)
EC, ECF & BC = enduit ciment-(Concrete pavement)

Note, the numbers in parenthesis refer to the maximum particle size of the aggregate, example 0/10, aggregate particles between 0 and 10 mm.

This paper describes the development process and future use of the equipment with special attention to turbulent air flow.


This paper describes a new and novel method to measure the acoustical (noise properties) of a pavement in the laboratory. A sample of a pavement surface 50 cm by 50 cm (approximately 18 inches by 18 inches) is brought into the laboratory. A solid cast model of half of a tire (note that the model replicates the tire tread pattern) is placed on top of the pavement surface. A noise wave (sound energy) representative of that made by a real tire is blown or directed at the cast tire model and pavement interface, and the degree of noise attenuation (damping) is measured. Results of this testing with a real pavement surface are compared to a standard marble surface to rate the degree of noise reduction due to the pavement surface properties, porosity and stiffness. Although limited testing is reported to date, the asphalt rubber surface developed by COLAS appeared to provide the greatest noise reduction.


The characterization of tyre-road contact noise has become of major concern in France. The multi-use Equipment SIRANO measures a form of tyre-road noise. Additional research is needed to standardize the measurements and relate them to currently accepted tyre-road contact noise methods.

In order to control the different phenomena responsible for the generation of tyre-road noise, contactors such as COLAS (French contractor of a proprietary quiet rubber pavement) have sponsored research such as that reported on in this paper. From this research it is reported that very porous pavements to a degree do reduce tyre-road noise but clog with time. As of yet no suitable or practical method has been found to eliminate such clogging. More closed textured (less porosity or air voids) surfaces such as that produced by COLAS provide a very good surface to reduce noise and appear to last longer. Tests were conducted with regard to noise reduction due to inter-granular absorption, less noise due to damping noise vibration and impedance technique. Such tests seem to confirm the author’s claims about the asphalt rubber product produced by COLAS.


The paper details how flexible pavement solutions were utilized to reduce the impacts of traffic induced noise and vibration to residents living along an urban arterial road. Noise measurements were made “before” and “after” for several types of road surfaces. An investigation of the noise attributes of the trial surfaces was performed using the statistical Pass-by method of data collections (ISO 1997). The results are presented in Table 4.7

### Table 4.7 - Noise levels of Abbot St Trial surfaces 1 month after placement.

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Noise Level (dB(A)) Comparisons relative to Dense Graded Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cars</td>
</tr>
<tr>
<td>Dense Graded</td>
<td>0</td>
</tr>
<tr>
<td>Boral “Novachip”</td>
<td>-1.6</td>
</tr>
<tr>
<td>Pioneer “Hushphalt”</td>
<td>-2.9</td>
</tr>
<tr>
<td>Boral “LoNoise”</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

LoNoise is a 7mm special gap-graded asphalt mix that has its origins in France and has been developed by Boral Asphalt Pty Ltd for use in Australia (see Reference Hennessy, 2003). It is comprised of aggregate, added filler; polymer modified bituminous binder and granulated rubber (recycled car tires and “crumbed” rubber”). Statistical pass-by method was used to compare the noise attributes of the new “LoNoise” asphalt surface to the dense graded asphalt surface that existed prior to the overlay. Noise reductions were measured at 5.0 dB(A) for cars, -3.6 dB(A) for medium trucks and at –3.5 dB(A) for heavy trucks. These values were comparable to those measured and reported on Table 4.8.
Table 4.8- Before vs After Traffic Levels on the Townsville Port Road

<table>
<thead>
<tr>
<th>Location</th>
<th>Before overlay Noise Level (dB(A))</th>
<th>After Overlay Noise Level (dB(A))</th>
<th>Noise Reduction (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>140 Boundary St</td>
<td>70.0</td>
<td>67.2</td>
<td>-3.8</td>
</tr>
<tr>
<td>184 Boundary St</td>
<td>71.2</td>
<td>66.9</td>
<td>-4.3</td>
</tr>
<tr>
<td>248 Boundary St</td>
<td>68.8</td>
<td>64.8</td>
<td>-4.0</td>
</tr>
<tr>
<td>288 Boundary St</td>
<td>64.9</td>
<td>61.6</td>
<td>-3.3</td>
</tr>
</tbody>
</table>


ACI Acoustical Consultants Inc. collected noise measurements to determine the amount of road tire noise on the AR hot mix sections and on the conventional asphalt pavement control sections. Several sound level measurements were taken at the three locations throughout the Edmonton area. These sections included:

- Hwy 630 (south-east of Edmonton) at RG RD 205 (speed limit 100 km/hr);
- 137 Avenue and 119 Street in Edmonton (speed limit 60 km/hr); and
- 17 Street and Baseline Road in Edmonton (speed limit 70 km/hr).

At each of the locations, two sets of measurements were collected. The first set was collected adjacent to the AR hot mix and the second set was collected adjacent to the new conventional asphalt surface placed as the control section. Road noise measurements were collected approximately three months after construction. In each case, the two locations evaluated were close enough to each other to obtain similar traffic patterns, but far enough apart that each road surface could be assessed independently. The measurements were conducted using a CEL 593 Type 1 Integrating Sound Level Meter. The instrument collected sound levels in overall Linear and a weighted levels as well as 1/3 octave band frequency analysis.

The results obtained along 137 Avenue are likely the most accurate of the three locations. This is mainly because the traffic patterns did not change appreciably between the two measured sections. There was slightly more variability in traffic at the other two measurement locations (as well as more varying background noise events at the 17 Street location). The sound levels were approximately 4-dB lower than on the conventional AC throughout much of the frequency range and the overall a-weighted sound level was reduced by approximately 4-dB. Also of importance is that the AR hot mix did not result in an appreciable increase in sound level at any of the frequencies compared to the conventional asphalt for any of the three locations. The noise measurement findings from this study are in agreement with other AR hot mix noise measurement in other jurisdictions. Figure 4.8 is an example of one of the sound intensity graphs.
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.

**Figure 4.8– Comparison of Sound Pressure Levels for Conventional and asphalt rubber pavements in Alberta.**

As shown in the report, the Noise readings before and after placement of the asphalt rubber were very much reduced. These locations were used for both the before and after readings. In Table 4.9 the averages in decibels for each location before and after paving with the asphalt rubber are provided.

**Table 4.9. Noise Data in Decibels (A weighted)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Before</th>
<th>After</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder (15m)</td>
<td>79.8</td>
<td>72.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Soundwall (30m)</td>
<td>76.6</td>
<td>67.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Residential (120m)</td>
<td>51.7</td>
<td>45.6</td>
<td>6.1</td>
</tr>
</tbody>
</table>

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. [Sandberg, 2002]


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 8 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.’ Figure 4.9 illustrates, before and after placement of the asphalt rubber mix, noise levels.
Figure 4.9 - Sound Pressure for before (over PCC) and after (over asphalt rubber) measurements for several sections of freeway. (Note measurements not taken to standard Pass-By protocol after further analysis the actual noise reduction on the order of 8 dB, (Rand 2004)


The study presents a remarkable new technology development in measuring noise by introducing the sound intensity method with its unique device. The device used in this method is featured with two tube-type microphone probes placed at leading and trailing edges of the tire contact patch so it measures “near-field” noise variable. Such a device can measure the sound intensity, which is directional and so is a vector, in the small proximity (say in a scale of foot or even inch) to the type/road surface. In theory, by using a two-probe configuration, this method can eliminate other noise sources and record the noise mainly from tire-road surface interaction in a direction of interest. Therefore, it can capture noise spatial distribution and is a much-advanced method from the science point of view. In addition, this device can be installed with a vehicle so it is mobile that can capture large noise data, in comparison with the pass-by method, in a relatively short time period, which is certainly an advantage.
Figure 4.10-Tire/Pavement Noise Sound Intensity (Donovan, 2003)
<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Additional Notes</th>
<th>SI Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ Marc 10</td>
<td>ARFC</td>
<td></td>
<td>96.6</td>
</tr>
<tr>
<td>CA Sac track</td>
<td>DGAC</td>
<td></td>
<td>96.7</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>OGAC 75 mm thickness</td>
<td></td>
<td>96.9</td>
</tr>
<tr>
<td>CA SM 280</td>
<td>RAC (Type O)</td>
<td></td>
<td>97.2</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>RAC (Type O)</td>
<td></td>
<td>97.2</td>
</tr>
<tr>
<td>AZ Marc 202</td>
<td>ARFC Best Condition</td>
<td></td>
<td>97.4</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>OGAC 30mm thickness</td>
<td></td>
<td>97.4</td>
</tr>
<tr>
<td>CA Fre 5</td>
<td>RAC (Type O)</td>
<td>High Binder</td>
<td>97.8</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>DGAC</td>
<td></td>
<td>98.3</td>
</tr>
<tr>
<td>CA SBd 40</td>
<td>RAC (Type O)</td>
<td>High Binder</td>
<td>98.4</td>
</tr>
<tr>
<td>AZ Marc 10</td>
<td>P-ACFC</td>
<td></td>
<td>98.7</td>
</tr>
<tr>
<td>AZ Marc 10</td>
<td>SMA</td>
<td></td>
<td>99.6</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>BWC New</td>
<td></td>
<td>99.9</td>
</tr>
<tr>
<td>AZ Marc 10</td>
<td>ARFC</td>
<td></td>
<td>100.0</td>
</tr>
<tr>
<td>CA SBd 40</td>
<td>DGAC Exist</td>
<td></td>
<td>100.1</td>
</tr>
<tr>
<td>AZ Marc 10</td>
<td>PEM Open Graded</td>
<td></td>
<td>100.6</td>
</tr>
<tr>
<td>CA LA 138</td>
<td>DGAC Reference Section</td>
<td></td>
<td>101.1</td>
</tr>
<tr>
<td>CA SM 280</td>
<td>PCC Ground</td>
<td></td>
<td>101.2</td>
</tr>
<tr>
<td>AZ Marc 202</td>
<td>ARFC Poor</td>
<td></td>
<td>101.4</td>
</tr>
<tr>
<td>CA Ker 58</td>
<td>PCC New Burlap (Longitudinal)</td>
<td></td>
<td>101.5</td>
</tr>
<tr>
<td>CA Yub 70</td>
<td>OGAC Aged</td>
<td></td>
<td>101.6</td>
</tr>
<tr>
<td>CA SCI 85</td>
<td>PCC New Longitudinal Tine</td>
<td></td>
<td>101.7</td>
</tr>
<tr>
<td>CA Sol 80</td>
<td>DGAC</td>
<td></td>
<td>101.7</td>
</tr>
<tr>
<td>CA Ker 58</td>
<td>PCC New Broom (Longitudinal)</td>
<td></td>
<td>101.8</td>
</tr>
<tr>
<td>AZ Marc 202</td>
<td>PCC Longitudinal Tine</td>
<td></td>
<td>102.0</td>
</tr>
<tr>
<td>CA Sac 5</td>
<td>PCC Aged Longitudinal Tine</td>
<td></td>
<td>102.2</td>
</tr>
<tr>
<td>CA SM 280</td>
<td>PCC Text. Grind (var. 8mm/0.1km)</td>
<td></td>
<td>102.3</td>
</tr>
<tr>
<td>CA LA 14</td>
<td>PCC Fair Longitudinal Tine</td>
<td></td>
<td>103.1</td>
</tr>
<tr>
<td>CA Ker 58</td>
<td>PCC New Longitudinal Tine</td>
<td></td>
<td>103.5</td>
</tr>
<tr>
<td>CA SM 280</td>
<td>PCC Aged Longitudinal Tine</td>
<td></td>
<td>103.8</td>
</tr>
<tr>
<td>CA SM 84</td>
<td>Chip Seal New</td>
<td></td>
<td>105.0</td>
</tr>
<tr>
<td>AZ Marc 202</td>
<td>PCC New Transverse Tine</td>
<td></td>
<td>107.1</td>
</tr>
<tr>
<td>AZ Marc 202</td>
<td>PCC New Random Transverse Tine</td>
<td></td>
<td>109.2</td>
</tr>
</tbody>
</table>

**Table 4.10 AC and PCC Pavements With Associated Sound Intensity Levels**

*Table Legend: Location is state, CA California or AZ Arizona, county and route number. Pavement acronyms are as follows: ARFC Asphalt Rubber Friction Course, BWC Bonded Wearing Course, DGAC Dense Graded Asphalt Concrete, OGAC Open Graded Asphalt Concrete, P-ACFC Polymer Modified Asphalt Concrete Friction Course, PCC Portland Cement Concrete, PEM Permeable European Mixture, RAC(Type O) Rubber Asphalt Concrete (Open Graded), SMA Stone Mastic Asphalt,*
This method along with the device was tested for various road conditions such as test track environments as well as actual highways for two tire brands: Goodyear Aquatred 3 P205/70R15 and American Silver P205/70R15. An effort was first made to compare what obtained in this method with the pass-by method. The comparison shows a very good correlation, which provides a validation for including this sound intensity method as a viable and efficient tool in measuring tire/road noise.

Then the major tasks were conducted in applying this method to record tire-road noise for more than two dozen road sections with different road surface and structure conditions which include PCC, ARFC, DGAC, OGAC, RAC (Type O), SMA, BWC, PEM with various thickness, binder content, age and tine treatment, etc in CA and AZ during the last half decade.

The finding by the sound intensity method is, as a group, PCC surfaces were found to produce higher noise levels than batch mixed AC surfaces. The highest number in dB(A) is the case is PCC with New Random Transverse Tine. Of the highway pavements tested, those asphalt surfaces that were open graded, rubberized, or both, produced the lowest noise levels (Table 4.10). The difference in noise level between the highest and the lowest for all those tested pavements is more than 10 dB(A). Identical data is presented in Figure 4.10.


This study addresses a number of key issues regarding noise-pavement relationship. The primary focus is to evaluate the acoustic properties of different pavements. The method of CPX was employed in this study as the major tool with great effort in measuring road noise along with the pass-by method. In addition, the sound intensity method was also employed as the assistance receiving from Caltrans as a collaborative effort. The pavement type evaluated under this study covered a broad range from ARFC to PCC, and the finding reinforced what reported in Donavan’s and Rymer’s that PCC with transverse tining would give rise to the noisiest pavement.

It is well observed that asphalt pavement offers much quieter ride than PCC pavement. However, the FHWA requirements did not allow pavement type as a mitigation strategy. The non-acceptance of pavement surface type, to a large extent, is based upon the belief that “quiet pavements” lose their noise attenuation characteristics after 3 to 5 years and hence are not a permanent solution. To explore the validity of such belief, a task was taken in this study to log both the roadway and roadside noise at a ARFC pavement section in the state of Arizona for over a period of more than 10 years. Both the CPX method and sound intensity method were employed for recording noise. The regression method was employed to quantify the noise increase versus pavement age. The finding was that an increase of about 5 dBA was seen during 10 years by the CPX method but little increase in dBA was seen for the sound intensity method.
The ARFC layer was of 5/8” thickness with a design life of 10 years. Thus, age might have affected the road surface and structure conditions for this particular test section, and the CPX method, in comparison to the sound intensity method, apparently was sensitive to the road smoothness condition and others. Therefore, based on the result of this study, claiming that aging would noticeably diminish the noise attenuation characteristics for flexible pavement appears non-substantiated.

The study also offers the first known case of wind effect, in which a two-day noise measurement was taken. A set of microphones were placed along the roadside and on day-1 with a pleasant breeze condition, they were recording in a coherent fashion as a group. But on day-2, wind gusts of 4 to 6 mph apparently made turbulence to the coherent pattern of noise recording experienced on day-1. The logged numbers were showing huge variation, and they had to be discarded.

A special CPX noise study was conducted to compare various concrete texture surfaces to an ARFC, Table 4.11. Results of that study clearly showed that the ARFC was the quietest surface tested.

Table 4.11 - Noise levels by surface type

<table>
<thead>
<tr>
<th>Noise Level</th>
<th>Surface Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>104.9</td>
<td>Random Transverse (Wisconsin)</td>
</tr>
<tr>
<td>102.5</td>
<td>Uniform Transverse (ADOT-3/4”)</td>
</tr>
<tr>
<td>99.1</td>
<td>Longitudinal (ADOT-3/4”)</td>
</tr>
<tr>
<td>95.5</td>
<td>Whisper Grind</td>
</tr>
<tr>
<td>91.8</td>
<td>ARFC</td>
</tr>
</tbody>
</table>

Figure 4.11 demonstrates one reason why ARFC are perceived to be so much quieter than a concrete surface. It was noted in the study that a concrete surface has a high peak noise level in the 1,000 to 2,000 Hz area which is very annoying to the human ear. In contrast an ARFC surface has a very much lower noise value in the same frequency range. The result of this combination would be a much quieter level of noise to the human ear notwithstanding that the overall reduction in the dBA noise level (normalized area under the curve) might not be that great in value.
Figure 4.11 1/3 Octave content of Sound intensity for PCC and AR-OGFC (Scofield, 2003)


A low noise road surfacing, called WhispA, has been developed and gives a 3 decibel (dBA) reduction in noise when compared with conventional Open Graded Porous Asphalt (OGPA). Previously OGPA was the lowest noise road surfacing available in New Zealand. To date three trials have been undertaken in New Zealand.

Figure 4.12 shows the concept behind the WhispA surfaces. It consists of a double layer of OGPA of a total mat thickness of 70 mm. The lower layer consists of a 16 mm OGPA, which can utilize lower quality aggregates with high polished stone value and a top layer of an 8 mm OGPA using high quality aggregates and a polymer modified binder.
Figure 4.12 - Double layer concept for low noise surfacings.

Figure 4.13 - Shows the spectral analysis before and after the placement of the WhispA surfacings (in blue). It is clear a reduction around the 1000 Hz frequency.

Figure 4.13 - Comparison of spectral sound analysis before and after the placement of WhispA surfacings (blue line).

A global spectral analysis comparison for several other surfaces is presented in Figure 4.14. It is clear that the chip seals are the noisiest surfaces and the significant reduction of the sound level around the 800 to 1200 Hz achieved by the WhispA surfacings.
Figure 4.14 - Spectral analysis of sound level of several surfaces.
The absorption coefficient of dense and porous road surfaces has been measured in the laboratory using core samples with 4 and 6 in diameter impedance tubes and with an impedance tube mounted vertically in situ on the pavement surfaces, Figure 4.15.

The peak sound absorption measured for fine and coarse mix aggregate porous surfaces suggests that the first peak frequency and the peak absorption coefficient magnitude is only slightly different for the two types of porous surfaces. Since the fine mix aggregate porous surface is smoother it is preferred since it should result in less tire tread impact noise and thus lower overall tire noise that the coarse aggregate surface, Figure 4.16.
Figure 4.16 – Comparison of sound absorption coefficient over OGFC

A porous surface of between 1.5 and 2.0 in. thickness is recommend for the type of porous surface examined, if a peak absorption frequency of about 1000 Hz is desired, so as to be most effective at reducing interstate highway noise from automobiles. Figure 4.17 shows the effects of pavement surface and air void content measured by the CPX NCAT trailer.

Figure 4.17 - Sound level A-weighted over several Superpave surfaces and one SMA surface measured by the CPX method NCAT Trailer.
The Public Works Research Institute (PWRI) in Japan has since 1993 been developing a new low-noise pavement named “Porous Elastic Road Surface” (PERS). This new pavement has a porous structure composed of granulate rubber made from old used tires as its aggregate and urethane resin as its binder. Its porosity is approximately 40 percent. Noise reduction levels are 15 dB(A) for cars and 8 dB(A) for trucks Figure 4.18, measured by the controlled pass-by method based on ISO 326 and ISO 7188. The authors refer in the paper to Drainage asphalt Pavement as DAP and to Dense Asphalt Pavement as DENAP.

![Figure 4.18 - Comparison between noise levels obtained for the three surfaces studied per class of traffic.](image)

The paper also refers to comparison made to investigate the “optimal” thickness of the PERS layers. Figure 4.19 indicates that optimal measurements are obtained with thickness of about 3 cm (for passenger cars).
Figure 4.19 - Comparison of the effect of speed and thickness on the noise levels measured by PERS and dense graded conventional surfaces.

Figure 4.20 shows the power spectrum calculated by measure noise data by using the regression analysis of the relation between the vehicle speed and all the 1/3 – octave noise data of the power spectrum, in order to adjust the difference in the vehicle speed measure din the dense graded mix and PERS. All-path power level indicated by “AP” in the figure means the sum mention of the entire 1/3 octave power spectrum. It is clear that above 800 Hz the he reduction in noise energy achieve by PERS.
Figure 4.20- 1/3 – Octave noise spectrum.

The authors indicate that although the surface has incredible noise reduction achievements the cost and durability makes them yet not fully available for routine use. However these experiments clearly indicate that the more rubber the better as far as noise reduction is concerned.


This study presented the comparison between noise levels generated by about the same traffic level on the same day driving at speeds between 10 and 120 kmh passing over two types of pavement surfaces; one an asphalt concrete surface about 7 years old and another a 9 month old ARFC (Figures 4.21, 4.22 and 4.23).

The measurements were made with noise meters from Brüel & Kjær model 2260 – as per specifications CEI 804 (2000) with filters at 1/3 octaves as per specifications Norma CEI 61260 (1995).
Figure 4.21 - General layout of the two sections evaluated.

Figure 4.22– General aspect for AC surface about 7 years old.
Figure 4.23 - General aspect of ARFC surface 9 months old.

The traffic volume is presented in Table 4.12 for two tests performed in the sections. The exact same traffic passed over the two test sections.

Table 4.12- Traffic volumes during 30 minutes intervals.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Vehicles</th>
<th>1º Test</th>
<th>2º Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISBON → LEIRIA</td>
<td>Cars</td>
<td>245</td>
<td>199</td>
</tr>
<tr>
<td></td>
<td>Trucks</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>LEIRIA → LISBON</td>
<td>Cars</td>
<td>270</td>
<td>202</td>
</tr>
<tr>
<td></td>
<td>Trucks</td>
<td>38</td>
<td>32</td>
</tr>
</tbody>
</table>

For each test the results are presented in Table 4.13. They were obtained at 6.5 meters from the centre of the lane.
Table 4.13—Noise levels at 6.5 m from the center of A8 freeway.

<table>
<thead>
<tr>
<th>Sound intensity dB(A)</th>
<th>ARFC</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1º Test</td>
<td>73,5</td>
<td>79,1</td>
</tr>
<tr>
<td>2º Test</td>
<td>73,5</td>
<td>78,6</td>
</tr>
</tbody>
</table>

It is quite clear the noise level reduction when the traffic passes over the ARFC section reaching 5 to 6 dB(A) coming from the conventional old AC layer. A spectral analysis as presented in Figure 4.24 allows us to identify that after 630 Hz the ARFC generates noise levels which much lower energy contents.

Figure 4.24 - Spectral analysis of noise the two tests conducted over a ARFC (AR-OGFC) layer 9 month old and a conventional AC layer 7 years old.

This study presented the comparison between noise levels generated by the same traffic level (198 passenger vehicles and 55 trucks) on the same day (November 13th, 2004) all driving with speeds between 10 and 120 km/h passing over two types of pavement surfaces; one a Continuously reinforced concrete about 8 years old and another a 9 month old ARFC (Figures 4.24, 4.25 and 4.26).

The measurements were made with noise meters from Brüel & Kjær model 2260 – as per specifications CEI 804 (2000) with filters at 1/3 octaves as per specifications Norma CEI 61260 (1995).

![Figure 4.24– General aspect of the two pavement surfaces investigated.](image-url)
Figure 4.25– CRC pavement surface.

Figure 26-ARFC pavement surface.
Table 4.14 - Comparison of noise levels obtained in the two pavement sections.

<table>
<thead>
<tr>
<th>Pavement</th>
<th>dB(A) @ 0.5 m</th>
<th>dB(A) @10 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement CRC</td>
<td>80.6</td>
<td>70.8</td>
</tr>
<tr>
<td>Pavement ARFC</td>
<td>72.6</td>
<td>62.3</td>
</tr>
</tbody>
</table>

It is quite evident as seen in Table 4.14, that there is a pronounced reduction in noise levels obtained by the ARFC. Varying between 8 and 10 dB(A) near the lane and 10 meters away.

**Figure 4.27 - Spectral analysis of noise the two tests conducted over an ARFC (AR-OGFC) layer 9 months old and a CRC Portland cement concrete pavement.**

The spectral analysis shown in Figure 4.27 identifies the significant difference in frequency content of the noise generated by the two surfaces. Around 1000 to 2000 Hz the noise content is much lower in the ARFC than in the CRC, thus easy listening on a quiet pavement.
Chapter 5 – Author’s Discussion

Why are asphalt rubber (AR) pavements less noisy than others most commonly used types of pavements?

The answer to this question is not simple. Although there is now an overwhelming body of evidence and research that supports the thesis that asphalt-rubber pavements generate less noise not enough has been researched to identify the causes.

Noise reduction capabilities of AR mixes has been widely demonstrated throughout this synthesis and the latest technology to measure noise developed and employed by Caltrans and ADOT research. This body of research work from these two state’s show unequivocally, that asphalt rubber pavements are quieter because less noise is generated at the tire/pavement interface.

Some have argued the primary reason for the noise reduction comes from the surface characteristics and the open graded nature of the aggregate gradation, which leads to the creation of air voids and air pockets that absorb the noise.

Others have argued that given that any new pavement does exhibit a noise reduction over an older surface, that binder content at the surface of the aggregate (before being removed by traffic) leads to sound being absorbed by the asphalt films.

Some believe that most of the sound reduction characteristics of low noise pavements are caused by the macro and micro texture. Examples of noisy surfaces are chip seals with PCC pavements with certain types of textures.

However there must be something particularly unique on AR rubber pavements and especially in open grade asphalt pavements that causes them to be rated as the quietest of generally used surfaces.

If it was air void content accounting for the noise reduction in open graded pavements differences between polymer modified and asphalt rubber pavements would be little different. Yet the AR mixes which basically have the same air void level content and identical macro and micro texture are quieter than the other pavements. Another example is that ADOT gets calls form citizens congratulating them when they use an ARFC and not when polymer modified binder is placed.

Ulf Sandberg proposes a relative influence of different factors and he identifies layer thickness to have a high influence on noise, for porous surfaces. ARFC’s are usually placed 12.5 to 25 mm (0.5 to 1 inch) in thickness compared to regular porous layers with 40 to 50 mm (approximately 1.5 to 2 inches) thickness. Furthermore the contribution given to stiffness (modulus) of the material does not appear to be clearly defined. If two spheres of granite aggregate are banged...
together a higher sound level is obtained than if two spheres of rubber of equal volume are used. Thus the influence of stiffness (modulus) cannot be neglected.

Table 5.1 – Parameters with a potential influence on tire/road noise

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Degree of Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Macrotecture</td>
<td>Very High</td>
</tr>
<tr>
<td>2</td>
<td>Megateture</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>Microtexture</td>
<td>Low-Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Unevenness</td>
<td>Minor</td>
</tr>
<tr>
<td>5</td>
<td>Porosity</td>
<td>Very high</td>
</tr>
<tr>
<td>6</td>
<td>Thickness of layer</td>
<td>High for porous surfaces</td>
</tr>
<tr>
<td>7</td>
<td>Adhesion</td>
<td>Low/Moderate</td>
</tr>
<tr>
<td>8</td>
<td>Friction</td>
<td>See microtexture</td>
</tr>
<tr>
<td>9</td>
<td>Stiffness</td>
<td>Uncertain, moderate (?)</td>
</tr>
</tbody>
</table>

Several facts contribute to noise reduction and based on the reports researched it can be concluded that beyond every other aspect present above the following key aspects appear to be the leading reasons why ARFC’s are less noisy:

- **Stiffness (Modulus).** The stiffness of this mix is lower than all other mixes used. Not only that stiffness is the lower when the mix is placed due to the very thick films of binder and the intrinsic AR binder properties but also because the mix does not age as much as the other types of mixes and therefore does not harden. It is well known that walking with high heels over a granite floor is far noisier than walking over a rubber mat. To get a better insight into the effect of stiffness at the surface contact it is worthwhile to look at the effect of the stiffness of tire rubber on noise levels. Ulf Sandberg reports that a very skilled R&D engineer at a major tire company placed a 2mm thick layer of extra soft material on the outer part of the tread (as the top material of the tread) and measured the noise for this tire as compared to the regular tire. The noise reduction measured was substantial. This is further evidence that “soft surfaces” are better at reducing noise than harder or harden surfaces.

- **Rubber content.** The existence of undigested crumb rubber at the surface, between the aggregate particles and also next to the air pockets not only acts directly as a sound absorbing material when directly hit by the tire but also absorbs the sound when penetrated in the air voids. Furthermore the rubber provides a barrier to sound propagation between each aggregate. To corroborate this hypothesis quoting Ulf Sandberg in, he states, “the inclusion of large fraction of rubber in the surface mix may result in lower noise”. He goes on to say that “in particular a surface where all granulates are made of rubber from scrap tires and which is porous may become “extremely quiet”. Some believe that the existence of the crumb rubber particles in the matrix of an ARFC is the major reason and key factor that leads to excellent noise reduction properties and it has.
- **Binder content.** The asphalt rubber open graded mixes such as ARFC contain between 9 and 10% of binder by weight of mix and is by far the mix that has the most binder content of all other currently in use. The thickness of the films of asphalt around each particle is about 10 times that of regular mixes. It is noteworthy to recall that in the car industry rubber and asphalt are used (sometimes combined) to reduce noise in rattling car parts. In this case the binder must be accounted for in its dampening effect.

- **Texture.** Texture of a surface mix is clearly important and Ulf Sandberg has extensively covered this aspect. Nevertheless ARFC noise reduction goes beyond what has been achieved just with improved or optimized textures thus justifying the conclusion that the other aspects presented (stiffness, rubber content and binder content) are the main reasons that lead AR mix to outperform all others.

Researchers which have designed mixes with higher crumb rubber contents using a dry method have indicated that significant noise reduction was achieved thus reinforcing the importance of the undigested crumb rubber in the ARFC mixes. The problem with the high crumb rubber mixes constructed using the dry method has been durability. Usually they ravel within relative short time period.

Data from Larry Scofield and Paul Donovan as shown below identified mixes that generate very low noise levels (around 94.5 dBA) even after 8 years of use. Given that randomly (either by “defects” of construction or material variability, not unlike Darwin evolutionary theories in which change and chance also plays an important factor in shaping evolution) it is possible that without trying, some excellent low noise mixes have already been placed, and it is important to find them and research what parameters make them behave in such a manner.
ARFC Noise Levels Versus Pavement Age

\[ y = 0.5453x + 93.279 \]

\[ R^2 = 0.5805 \]

Figure 5. Variation of CPX noise levels with age in ARFC mixes (Donovan, 2003)

At the outset it would be easy to speculate that mixes that have higher binder contents, higher percentage for larger crumb rubber particles and probably higher air-void content. What would be interesting to investigate also is what has kept them performing so well so long. AR mixes were never designed to either consume large amounts of crumb rubber or to be low noise surfaces. Mostly they have been designed for durability and high resistance to reflective cracking. It is unlikely that those combinations may have lead to an optimization in noise level reduction thus it is foreseeable that a lower noise mix can be achieved even if a compromise on the other long lasting performance is needed. In some cases some highway agencies may be willing to accept less reflective cracking and durability performance in exchange for 5 or 7 years for extra low noise surfaces.
Traffic noise has been an issue that essentially started with the invention of the wheel. From time to time the noise levels associated with the tire/pavement interaction reached levels that led to restrictive regulations. In some cases the limitations even led to reduction or elimination of traffic with obvious other negative significant impacts.

Many have been the studies and solutions developed to measure and mitigate noise in roads and freeways. This synthesis has presented some findings from numerous selected studies.

Not unlike many other areas of the human development, in the area of noise reduction solutions develop for one purpose find greater utility in another area. This synthesis compiles information from the use of several technologies developed throughout the years to measure noise levels as well as on noise levels generated over several types of surfaces.

It is apparent that measuring directly the noise generated at the tire/pavement interface leads to a much clearer identification of the effect that different surfaces have on the overall noise levels generated on the freeway system. Such measurement has only recently been possible due to the newly developed CPX measurement system that can actually record noise levels at the tire/pavement interface.

The CPX system clearly identifies that asphalt rubber pavement surfaces generate the least noise of all other currently used pavement surfaces. Curiously these pavement surfaces were not designed with noise reduction in mind. The noise reduction levels are so significant in fact that at times citizen groups voiced their strong desire that asphalt rubber be placed on a freeway to minimize noise levels.

From the compilation of the data and analysis of the data from numerous studies reviewed for this synthesis the following conclusions can be derived:

- Roadside measurements have shown that asphalt rubber friction courses can achieve 3 to 5 dB noise level reduction when compared to traditional asphalt dense graded surfaces and 6 to 12 dB noise level reduction when compared to concrete surfaces.
• Sound intensity measurements (CPX) have shown that asphalt rubber surfaces are effective in reducing noise by 4 to 6 dB compared with traditional dense graded asphalt concrete and by 6 to 12 dB when compared to concrete surfaces.

• Tire-pavement noise studies have indicated that an asphalt rubber open graded friction course has a greater potential for attenuating traffic noise when placed over old flexible or rigid pavement surfaces. The asphalt rubber open graded friction course also has other significant positive safety benefits for the public such as controlling hydroplaning, minimizing water spray from the trucks, reducing aging and oxidation. Pavement markings placed on this open graded surface also provide higher visual contrast for vehicle guidance.

There is much speculation about the reasons why asphalt rubber mixes generate less noise. It is postulated that a combination of reasons lead to this fact such as: (1) they are less stiff then all other mixes currently used, (2) they contain the highest crumb rubber content, (3) they also contain the highest binder content and (4) they support an adequate texture and air void content.

It is well known that low stiffness surfaces and high viscosity interlayers are key aspects in noise reduction and mitigation techniques. The sound does not propagate well through two aggregates if between them is a soft crumb rubber particle well embedded in a thick viscous film of asphalt. This also affects the energy content at each frequency. In particular it appears that this combination reduces sound pressure at the frequencies the human ear is most sensitive to. The added benefit of this crumb rubber-high binder is improved durability and low stiffness during many years of service. This insures that the low noise levels remain low throughout the years as the mix maintains its initial properties.

Sound walls are an obstruction for errant vehicles and their removal may improve overall roadway safety. Furthermore sound walls do not contribute for noise reduction for vehicle occupants. Lowering the noise the driver can hear may well reduce fatigue, “road rage” and accidents. If there is a need for future widening the existence of a wall will delay the process and will increase the cost of the project. As such it will really be cost effective to take advantage of any and all methods to reduce noise generation at the source.

Much has been learned about measuring the noise from the tire/pavement interface and much more will be learned in the future. Research on how to design quieter pavement surfaces is needed, as even quieter, safe and durable asphalt rubber surfaces appear possible.
As such it is recommended that investigations be carried out to determine if it is possible to develop mix designs to reduce even more the noise levels attenuated by asphalt rubber surfaces as compared with other surfaces.

Introduce into existing noise models the capability of investigating the cost benefit ratios derived from the use of different types of pavement surfaces. This may lead to the clear identification that pavement surfaces can actually be expensive but if they can reduce significantly noise levels, they will be very cost effective (as the cost of wall construction may be significantly reduced).

It is further recommended that noise reduction be used as an objective part of pavement preservation goals. Routine noise measurements can be made as part of pavement management systems and develop a criteria for trigger levels that will require the use of asphalt rubber solutions.

Extend the Noise synthesis study to address the recommendations above.

**Acknowledgements:**

The authors wish to thank Bruce Rymer from CALTRANS and Larry Scofield from ADOT for all their help in providing new and valuable research findings to this report. Thanks are also due to Doug Carlson and Donna Carlson in their patience in waiting for this Synthesis report to be completed.

The authors also want to particularly thank and acknowledge the contributions of George Way, Dr. Shakir Shatnawi, and Prof. Kamil Kaloush.

The support of RPA is truly appreciated.
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Appendix A
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HIGHWAY TRAFFIC NOISE ANALYSIS AND ABATEMENT POLICY AND GUIDANCE

by

U.S. Department of Transportation
Federal Highway Administration
Office of Environment and Planning
Noise and Air Quality Branch
Washington, D.C.
June 1995

Pavement

Pavement is sometimes mentioned as a factor in traffic noise. While it is true that noise levels do vary with changes in pavements and tires, it is not clear that these variations are substantial when compared to the noise from exhausts and engines, especially when there are a large number of trucks on the highway. Additional research is needed to determine to what extent different types of pavements and tires contribute to traffic noise.

It is very difficult to forecast pavement surface condition into the future. Unless definite knowledge is available on the pavement type and condition and its noise generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels. Studies have shown open-graded asphalt pavement can initially produce a benefit of 2-4 dBA reduction in noise levels. However, within a short time period (approximately 6-12 months), any noise reduction benefit is lost when the voids fill up and the aggregate becomes polished. The use of specific pavement types or surface textures must not be considered as a noise abatement measure.
Appendix B
– Arizona DOT Quiet Pavements Program
NEWS

Adding rubberized asphalt to majority of Valley freeways

Quieter freeways and a resourceful use of old recycled tires will be the primary results of a plan to add a rubberized asphalt surface to a majority of the Valley’s freeway system.

Approximately 130 additional miles of Valley regional freeways will be resurfaced with rubberized asphalt starting later year under the plan unveiled back in December.

The freeway-surfacing plan, developed by the Arizona Department of Transportation (ADOT), the Maricopa Association of Governments (MAG) and local cities, will be accomplished over three years.

Officials have faced the challenge of funding the rubberized asphalt, which reduces tire noise. They’ve agreed to use $34 million from other MAG regional transportation funds and projects to pay for the freeway resurfacing.

ADOT has already used rubberized asphalt throughout the state, and more recently, on section of Interstate 17, the Superstition Freeway (US 60) and the Loop 101 in the Valley.

“This is a major milestone for our citizens,” said ADOT Director Victor Mendez. “We’ve been looking for ways to respond to what many of our customers have been asking for. All the meetings with the citizens and mayors are paying off.”

The plan will add rubberized asphalt to the entire 60-mile Loop 101 plus sections of the Loop 202, State Route 51, I-10 and I-17.

The key ingredient in rubberized asphalt is “crumb rubber,” granules of shredded recycled tires. The crumb rubber is mixed with heated liquid asphalt and stones before being applied to a freeway as a one-inch surface pavement.

Noise readings have shown the rubberized asphalt generally reduces tire noise by 3 to 5 decibels.
Appendix C

The Ear of the People

Articles reprinted from “The Arizona Republic” and the “East Valley Tribune” local newspapers in the Phoenix Metropolitan area. These articles express the concern of the Phoenix Metropolitan area community with respect to annoyance of freeway noise. The citizens spoke and ultimately government listened and developed the Quiet Pavement Program to bring peace to the Valley of the sun. The Authors express many thanks to Republic and Tribune newspapers for making these articles available, and making the voice of the people heard.
ADOT agrees noise problem exists

Study reveals excessive decibels along Loop 101

By Jen Osbom
SCOTTSDALE VIEWS

Scottsdale residents living along the Loop 101/Pima Freeway have been complaining of too much noise and the state agrees.

Officials from the Arizona Department of Transportation told the City Council during a work-study meeting Jan. 28 that noise studies show that residents’ complaints about excessive noise along much of the highway are founded.

“It’s basically the whole corridor. It’s all the way from McKellips Road pretty much up to Frank Lloyd Wright Boulevard,” said Angie Newton, senior transportation planner for ADOT.

Any Corathers, transportation planner for the city, said the presentation was a chance for ADOT to come forward and tell the council what they know about the noise problems and what can be done to fix them.

“It seems straightforward, but it’s a very complex issue we’re finding out,” Corathers said, explaining that people have different definitions of noise.

Newton said the study was presented at the council after ADOT spent several months taking readings, beginning last summer. Some areas were exceeding acceptable noise levels, and action was recommended to muffle the noise. However, the city asked them to take more measurements because residents complained that the winter months brought more traffic.

“We did in fact get higher readings,” Newton said. “By doing so many noise readings we wanted to get a gauge about how bad the noise really was.”

She said louder traffic could be traced back to an increase in cars on the freeway from winter visitors. Also, she said traffic consultants think the colder temperatures stiffen vehicle tires, causing them to generate more noise.

Newton said some neighborhoods with noise problems were developed after the freeway was planned, but builders didn’t take freeway noise into consideration by creating proper buffer zones for their residents. Other portions of the city were already developed, but traffic became worse than expected and noise levels increased, lessening the buffer’s effectiveness.

Now that they know there’s a problem, Newton said ADOT representatives will decide on the most cost-effective solutions for residents. They’ll share those ideas with city staff and then take the data to as many as 20 individual neighborhoods to gauge residents’ opinions. She thinks neighborhood meetings may start in three or four months.

But Newton said more studies and plans must be done before that happens. Once areas where noise impact occurs are located, engineers must estimate the level of noise 20 years down the road.

“You don’t just try to fix a problem now, you look at what it’s going to be in the future,” she said.

Although the City Council asked ADOT for a quieter rubberized asphalt on the freeway, Newton said ADOT is hesitant because the material is expensive and may not stand up over time. She said the Federal Highway Association hasn’t approved the rubberized asphalt as noise mitigation because not enough studies have been done on its deterioration rate. They also fear the pavement could pose safety problems.

““There are a lot of issues. In the beginning, there’s no doubt, it definitely reduces noise, but the concern is long-term effects,” Newton said. “It’s not just an easy solution or one single problem.”

She said ADOT officials are just as concerned as residents near Loop 101 and have made freeway noise one of their top priorities.

The Arizona Republic, Wednesday, February 6, 2002
Making noise about Pima

Motorists make their way onto the southbound Pima Freeway from the Shea Boulevard onramp. Scottsdale is examining ways to mitigate noise on the busy freeway, officially called the Loop 101.

Scottsdale looking at ways to lower decibels from Loop 101

By Lesley Wright
The Arizona Republic

Scottsdale spent $5 million to make sure that its Pima Freeway walls have the best art in the Valley. Now, city officials might have to return to the bank to ensure that their residents also drive on one of the quietest roads in the region.

Beginning in October, contractors will travel mile by mile up Scottsdale’s stretch of Loop 101 and figure out how to resolve the noise issues besetting one neighborhood after another.

City officials made that decision after listening to the auditory nightmares of residents last winter and realizing this summer that the Arizona Department of Transportation would offer limited aid.

“What we’re not hearing is an acknowledgment from ADOT that there is a problem here,” City Councilman Ned O’Hearn said at one of a series of meetings the state held with neighbors this summer.

The first segment of Loop 101, from University Drive in Tempe to Thomas Road in Scottsdale, opened in 1996. And the complaints have been rolling in ever since, acknowledged Bill Hayden, ADOT’s ombudsman.

Since February, transportation officials have conducted noise readings on three key freeway segments in Scottsdale and made some preliminary determinations about who will get help. The news was good for some, questionable for others and downright bad for a good many.

A complex web of policies and logistical problems dictate how the transportation agency will deal with noise issues. Residents might clamor for new, quieter rubberized asphalt, for example. But ADOT can’t use it because the federal government does not recognize its beneficial effects and will not fund it.

Another concern relates to the “Date of Public Knowledge,” when residents learned the freeway was coming. On July 24, 1985. If a home was built after that date, the responsibility for noise is up to the developer or the city.

ADOT’s new tests also led to the discovery that decibel levels generally are higher in the winter than in the summer, a puzzling finding that has generated a whole new area of study.

“The issue remains, how do we address noise in the city of Scottsdale?” asked Michelle Korf, Scottsdale’s transportation...
PIMA Freeway noise solution sought

From Page 1

planning director.

The answer varies by neighborhood.

ADOT found that wintertime noise was above tolerable levels in the Trails neighborhood, where Pima Road rides the freeway from McDowell to McKellips roads. But the agency’s policies might keep it from doing much about it.

Jim Bateman, who moved into the Trails neighborhood in the 1970s, “when the only noise from the east was rattlesnakes and crickets,” left a neighborhood meeting with ADOT officials in disgust.

“Essentially, it was a Catch-22, a normal government situation,” Bateman said. “ADOT builds the freeway. Because of the way they build it, they can’t buffer us. We ended up getting totally abused, and it really upset a lot of people.”

Yet neighbors in the McCormick Ranch area, which runs from 90th Street to Mountain View Road, will get the rubberized asphalt on their stretch of road — courtesy of the Transportation Department.

The decision was based on a trade-off with the neighbors, who did not want a sound wall, ADOT spokesman Doug Nintzel said.

Cactus Road communities will have to wait for the end of studies.

Tom Fraker, a Scottsdale resident who has lived with the Pima Freeway noise for more than a decade, said that’s OK.

“You will not wear me down,” he told city and state officials during the series of meetings this summer.

Reach the reporter at lesley.wright@arizonarepublic.com or (602) 444-6883.
Rubberized asphalt wins quiet praise
Let the rubber be the road

Barren sections of East Valley freeways are finally getting landscaped, which helps make a daily commute more aesthetically pleasing.

And certain sections of those freeways are now being overlaid with "rubberized" asphalt, a combination of rock and liquefied tire rubber, oil and asphalt that makes freeway traffic quieter.

As new sections of freeway open near established neighborhoods in the East Valley, residents are demanding that the Arizona Department of Transportation pay as much attention to how they sound as how they look. It's a legitimate gripe, and it's good to see ADOT responding.

But ADOT in turn should exert more pressure on the state's congressional delegation for funding for rubberized asphalt on all freeways, not simply on sections that generate the most complaints. Rubberizing all Valley freeways would really have motorists — and the roadways' neighbors — cheering.

The combined low-pitched hum and high-pitched whine from vehicles traveling on concrete isaudial pollution both to freeway travelers and those living and working nearby. The sound is loudest at rush hours, particularly in the morning and in winter.

Moreover, rubberization cushions bumps to provide a smoother ride for those in vehicles and helps extend the lives of those vehicles' suspensions and shocks.

Currently ADOT has or is in the process of installing rubberized asphalt on U.S. 60 from Tempe to Val Vista Drive in Mesa and on the Loop 101 in Scottsdale from 90th Street north to Mountain View Road. These are areas where residents have complained the loudest, and for good reason.

But good-quality rubberized asphalt will noticeably cut freeway noise anywhere and should be applied to quiet vehicle noise throughout the Valley.

Local highway engineers should not fear some previous incarnations of the product during the early 1990s, which, as the Tribune's Jennifer Ryan reported Tuesday, failed to reduce noise. Technology has advanced to produce an improved product that benefits so many. Rubberized asphalt is quieter. It treats vehicles better. It even recycles hundreds of thousands of old tires and many gallons of used oil.

Since Arizona is only getting back about 90 cents of every transportation tax dollar we send to Washington, D.C., our representatives in Congress should have no qualms about seeking federal funding for rubberized asphalt — or the hum and whine will go on.
Tall noise walls and an asphalt that contains shredded tires lower the din of the freeways.

Steve Youngs is dwarfed by the 28-foot-tall wall in his Tempe backyard that reduces noise from the Superstition Freeway.
Rush hour to shush hour

By Ashley Tach
The Arizona Republic

Small miracles are popping up along Valley freeways these days.

Drivers are turning down their radios and wondering what happened to the racket of tires on concrete.

Neighbors trapped in their homes by the rush of traffic are rediscovering their back yards.

And everyone seems to be asking the same question: Since when did freeways become so quiet?

Commuters and residents from Tempe to Glendale are reaping the benefits lately of taller noise walls, freeways built below ground level and a special sound-killing weapon known as rubberized asphalt.

The people-friendly freeways result from a focus on livability. The state and some Valley cities are spending millions of dollars to muzzle the din of traffic.

And not a moment too soon. Savvy residents armed with their own noise meters and horror stories are demanding action as never before. Gone are the days when a freeway would barrel through a neighborhood without a glance.

"I think (the state) has come to realize it's a big problem," said Bob Willey, who this year founded the Scottsdale-based Citizens Against Noise. "Do people have a right to some peace and quiet in their residential communities during the hours they want to live there?"

Homeowners say the improvements make a world of difference. Steve Younghans said he doesn't appreciate the way crews tore up his back yard in Tempe to build a 26-foot-tall wall along the U.S. 60 (Superstition Freeway), but he can't argue with the results, particularly from a quieter asphalt surface.

A dusty television in his garage tells the story.

Walls, asphalt to reduce noise levels

The Arizona Department of Transportation plans to reduce noise levels on Valley freeways through the use of sound walls and rubberized asphalt. Here are the locations and dates of recent, current and upcoming projects.

Wall projects

- Northern wall near 59th Avenue
  Start: June 2002
  Finish: October 2002

- Southern wall near 59th Street
  Start: Spring 2003
  Finish: Fall 2004

- Western wall, near 50th Street
  Start: Spring 2003
  Finish: Spring 2003

- Western wall at Guadalupe Road
  Start: June 2003
  Finish: Early 2003

- Eastern wall at Montecito Court
  Start: October 2002
  Finish: October 2002

- Eastern wall just north of Ray Road
  Start: June 2002
  Finish: June 2002

- Tempe wall: drive in June and wrap up this month

Freeway of the future

The state is hoping to one day pave all Valley freeways with rubberized asphalt.

1 inch of rubberized asphalt
12 to 14 inches of concrete
4 inches of asphalt

The rubberized asphalt coats down on noise anywhere from 3 to 6 decibels. The material is a mixture of shredded tires, pea-size stones and liquid asphalt. The rubber from the tires gives freeways a smoother surface and helps create air pockets that absorb noise rather than reflect it.

Noise held at a minimum

By using rubberized asphalt, ADOT is trying to keep freeway noise at 64 decibels. A comparison:

180 - Chain saw, siren
100 - Noise of floor
86 - Loud movie trailer
64 - Freeway with rubberized asphalt
59 - 35 dB library
30 - Quiet living room

Mario Ramirez reaches for a brick while he and co-workers add about 6 feet to a noise wall on the U.S. 60.
SHUSH Softer asphalt cuts road noise

From Page B1

"This TV has been out here for six or seven years," he said. "I've never been able to watch it until now."

After raising urban noise standards two years ago, the state has been busy.

Besides the taller noise walls along the U.S. 60, crews are expanding walls along the Loop 101 in Scottsdale and north Phoenix. New projects such as the Santan Freeway will travel under most major streets, and several miles of improved noise walls are planned for the Squaw Peak Freeway.

Rubber meets the road

Perhaps most important, rubberized asphalt has emerged nationally as a clean and simple way to cut down on noise. The smooth blend of shredded tires, stone and liquid asphalt already graces the U.S. 60 to Mesa and Interstate 17 in Phoenix and has received rave reviews from both drivers and residents.

"ADOT is just having to grow up to the fact that noise is going to be part of their engineering of the future."

— Bob Willey
Founder of the Scottsdale-based Citizens Against Noise

The state would like to see all Valley freeways eventually paved with the material, which cuts down on sound by 3 to 6 decibels.

"We're sold on it as a noise mitigation measure," said Doug Nintzel, spokesman for the Arizona Department of Transportation.

But fighting freeway noise is expensive, and the state has little money to devote to the cause. A half-cent sales tax approved in 1985 for freeway construction is due to run out and was never designed to pay for significant noise measures, Nintzel said.

The state's inability to fully address the issue has caused some cities to pay for their own studies and noise walls.

Phoenix voters approved $8 million last year in a bond election for freeway landscaping and noise control, although the city has yet to start spending it. Glendale is wrapping up construction this month on new noise walls along the Loop 101.

"ADOT's not doing it," said Dan Sherwood, a Glendale senior civil engineer. "If you want it done, you need to do it.

Many residents agree. "ADOT is just having to grow up to the fact that noise is going to be part of their engineering of the future, but without money, what good is it going to do?" Willey wondered.

The price tag is high. Noise walls on both sides of a freeway cost $2 million a mile, and the state estimates it would cost $100 million to pave the entire Valley freeway system with rubberized asphalt.

When the freeway tax runs out in 2005, the state is hoping to use new noise control measures as a selling point to extend the tax.

"We need to start talking about quality-of-life issues when it comes to the next generation of work we're going to do on the freeways in this area," Nintzel said.

Issue is here to stay

The noise issue may never go away.

Questions still persist over rubberized asphalt's durability, and some residents complain that noise walls only send the sound over some homes and into others.

Living in the Valley will continue to be a decidedly urban experience, Nintzel said:

"It's not going to be to be the pristine desert environment," he said. "There's only so much you're going to accomplish in terms of noise, and you can't eliminate it all."
Rubber surface might reduce noise on road

By Kirsten Sorensen
Scottsdale Republic

SCOTTSDALE — After this weekend, the rubber will no longer meet the road on a section of the Loop 101 Pima Freeway. Instead, the rubber will meet the rubber.

Loop 101 between 90th Street and Shea Boulevard will be closed from 10 p.m. Friday to 5 a.m. Monday so crews can pave over part of the freeway with rubberized asphalt.

The project is part of a $2.8 million plan to shush traffic noise along Loop 101. In Scottsdale, it’s designed to dampen the din in the McCormick Ranch area.

“If you were to come out in our yard at 7:30 in the morning, the roar is unbearable. You can’t stay out there,” said Scottsdale resident Tom Frazer, who lives five blocks from the freeway and is encouraged by the news.

Typically, noise-dampening tactics translate to sound walls. This time, residents asked that rubberized asphalt be used instead. It’s a blend of shredded tires, stone and liquid asphalt. All that’s needed is a 1-inch layer.

The rubberized asphalt also will be placed on the interchange ramps north of 90th Street and on the Via Linda crossing beneath the freeway.

See NOISE Page 2
NOISE Freeway tries new top

From Page 1

Bob Willey, who founded the Scottsdale-based Citizens Against Noise and lives "smack dab in the middle of it," is disappointed, because he doesn't believe the rubberized asphalt will be placed where it can be most effective.

He would like to see the paving extend further into his neighborhood.

"It's a sad thing for everybody. It's not going to be an effective demonstration of what rubber can do," he said.

Doug Nintzel, a spokesman for the Arizona Department of Transportation, said some neighborhoods did not qualify for rubberized asphalt because their decibel levels weren't high enough.

The state would like to see all Valley freeways eventually paved with the material, which can reduce sound by 3 to 6 decibels. Noise walls on both sides of a freeway cost $2 million a mile, and the state has estimated it would cost $100 million to pave the entire Valley freeway system with rubberized asphalt, a cost of about $75,000 per lane per mile. When the freeway tax runs out in 2005, the state is hoping to use new noise-control measures as a selling point for another tax.

"We need to start talking about quality-of-life issues when it comes to the next generation of work we're going to do on the freeways in this area," Nintzel said.

Rubberized asphalt has emerged nationally as a clean and simple way to cut down on noise. The blend already graces U.S. 60 to Mesa and Interstate 17 in Phoenix.

"We don't want people to expect miracles. They still will be able to hear noise in the area," Nintzel said.

The portion of the freeway affected will be closed from 10 p.m. Friday to 5 a.m. Monday. The construction, which affects both northbound and southbound lanes, will depend on the weather. Rubberized asphalt must be applied when road-surface temperatures are above 75 degrees.

Reach the reporter at kirsten.sorenson@scottsdalerepublic.com or (602) 444-6843.
Quieter roads rallying fans
Rubberized asphalt cutting noise by 25%

By Bob Petrie
The Arizona Republic

It's the new miracle cure for excessive freeway noise, and everybody wants it.

Sound-absorbing rubberized asphalt has become the rage among drivers and people living in neighborhoods recently invaded by the Valley's fast-growing freeway network.

"I think it's fabulous," said Debi Nielson, 49, of Tempe, a radio advertising saleswoman and neighborhood activist, who enjoys the quiet ride of the Superstition Freeway (U.S. 60) since the rubberized asphalt was applied last summer.

People in her neighborhood along the Loop 101 (Price Freeway) south of Guadalupe Road are now thinking it might be helpful there.

About 150 turned out last week for a meeting on noise with representatives of the Arizona Department of Transportation.

"It definitely has affected the quality of life of the residents. It's waking people up at night," Nielson said.

ADOT spokesman Doug Nnatzol, who attended the meeting, said the request wasn't new.

"We hear that question all over the Valley from people near the freeways: 'Is that rubberized asphalt coming to our area?'"

See ROADS Page B3

Find an interactive graphic of Valley freeways and printable online maps at traffic.azcentral.com.

Motorists travel a portion of the Loop 101 in Scottsdale repaved with rubberized asphalt. Workers (top) use a blend made from shredded tires to coat a road's surface.

The Arizona Republic, November 21, 2002
ROADS

Noise remedy cuts din

From Page: B1

ADOT appears willing to remove the noise requirements for using rubberized asphalt and expand its use but only if it can find other ways to cover the $350,000 per mile cost.

The agency says it doesn't have the $100 million it estimates it would cost to pave over Valley freeways and is talking with cities including Chandler, Glendale, Mesa, Peoria, Phoenix and Scottsdale about chipping in.

"We may need to move beyond that in realizing this is a quality-of-life issue," Nintzel said.

When placed atop concrete, the porous, inch-thick layer of recycled crumbled rubber and asphalt traps and absorbs the loud whine of tires. A regular concrete surface, by comparison, bounces noise into the air.

ADOT says the surface reduces sound levels up to 25 percent.

Chandler Mayor Boyd Dunn is arm-twisting ADOT for rubberized asphalt on the Santan Freeway (Loop 202). Construction on the Santan starts in his city next year.

"To me, it makes sense to deal with how the noise is initially created, the tires on the road surface," Dunn said.

Right now, the highway department won't consider noise-reduction measures on freeways, such as asphalt or sound-reducing walls, unless there is a measured level of at least 64 decibels in adjacent neighborhoods.

About one mile of Loop 101 (Pima Freeway) at 90th Street in Scottsdale was paved with rubberized asphalt last weekend because of pressure on the city and state from neighbors who organized more than a year ago to protest the noise levels.

"We still have the traffic, but it's really been cut down as far as the noise goes," said Ralph Eisner, 69, a retired schoolteacher who lives next to the freeway.

Next year, a 10-mile stretch of Arizona 51, from Interstate 10 to Shea Boulevard, will get the rubberized asphalt surface as it's rebuilt to accommodate new carpool lanes.

Despite the new interest in rubberized asphalt, the Federal Highway Administration will not allow ADOT to use it as a noise-reducing tool on federally funded projects. Tire dust and oils from traffic eventually fill the pores in the asphalt, raising questions over the pavement's long-term effectiveness at lowering sound levels. Sound walls are considered a more permanent noise solution.

So ADOT uses rubberized asphalt mostly on older freeways, such as Interstate 17 in Phoenix and U.S. 60 in Tempe and Mesa, to preserve aging pavement and give the roadway a uniform look. New noise walls were also built along both freeways, leading ADOT to call the sound relief from the asphalt a bonus.

Nintzel says a "patchwork approach" of rubberized asphalt will succeed only in up-setting neighbors who don't get the surface on roads near them.

"The minute we would say we would do it in a longer stretch in one area, another part of the Valley will want us to do it there," Nintzel said.

Nielsen's neighborhood currently doesn't qualify for any noise walls or asphalt, but ADOT agreed to do more noise testing this winter, when residents say traffic seems louder. Scottsdale is also funding its own noise study for Loop 101.

Cities are also getting rubberized asphalt fever. Scottsdale has paved a few stretches of city streets with the material, and council members in Gilbert and Tempe are asking about resurfacing some of their streets.

However, Glenn Kephart, Tempe's public works director, said since streets are paved with asphalt, rubberized pavement wouldn't help much. Also, cars travel slower on arterials than on freeways, with more noise coming from motors than tires.

"I'm not as sure we would get as big a bang for our buck on our streets," Kephart said.
EDITORIAL

Costly problem created by rubberized asphalt

Our stand: Now everyone wants quieter freeways, but money for repaving is short

The recent repaving of Loop 101 sounds beautiful. Actually, there isn't much sound at all, and that's what's beautiful.

Loop 101 through parts of Scottsdale always has been a vision of loveliness as freeways are concerned. The extra money the city put into making a corridor of miles upon miles of concrete and asphalt pretty was well spent. When you commute on the 101, you know when you've hit Scottsdale because of the extra care given to landscaping and art. You see the difference.

And now you can hear the difference. As of last week, you know when you've hit a tiny part of Loop 101 through Scottsdale. It's smooth and extremely quiet.

Loop 101 was repaved Sunday from 90th Street to Shea Boulevard with the quieter rubberized asphalt. The effort was an attempt to reduce freeway noise for a McCormick Ranch neighborhood seriously disturbed by traffic.

The difference the surface makes is remarkable. Both drivers and neighbors are pleased with the quiet.

But in a sad way, this tiny piece of freeway heaven creates a devilish problem for transportation officials and neighborhood preservationists. Once you lay down the proof of noticeable change for the better, it's hard to back away from it.

Neighbors to the north and south of the stretch of rubberized asphalt are going to want the same noise abatement. Can you blame them? Ride the Loop. No, you can't blame them.

You might not be able to accommodate requests for quiet, either. Repaving with rubberized asphalt isn't cheap, something like $300,000 a mile. With a sluggish economy and a push to get other Valley freeway projects done, money for an expanded repaving project on Loop 101 isn't going to be easy to find.

Still, city and state officials will be hard-pressed to ignore the proof of significant improvement to the quality of life for neighbors of Loop 101.

Hearing is believing.
Squaw Peak Freeway extends its reach

By William Herrmann
The Arizona Republic

What began as a city parkway, then became a dead-end expressway, soon will become a connected, widened, full-fledged freeway.

Work began last week on laying the pavement for the final two-mile stretch of Arizona 51, also known as the Squaw Peak Freeway. The freeway now ends at Bell Road but will open to the Loop 101 in north Phoenix in June.

But don't think this freeway is finished. Early next spring, work will begin to widen the Squaw Peak to four lanes in each direction in its southern stretch and cover it with a layer of the rubberized asphalt that is impressing drivers in the East Valley.

Still, things are ahead of schedule. "We originally planned to link the Squaw Peak to the Loop 101 in 2005," said Matt Burdick, an Arizona Department of Transportation spokesman. "But the city of Phoenix agreed to pay the interest on a loan ADOT took out to finish the work earlier."

See FREeway Page A2
Coming soon

Other freeway openings in the next two years:
- On Jan. 13, Loop 202 (Red Mountain Freeway) will open from Greenfield to Highley roads in Mesa.
- In December 2003, the five-mile stretch of the Loop 202 (San Tan Freeway) from Interstate 10 to Loop 101 will open.
- In the spring of 2004, construction on the Loop 202 stretch between Highley and Power roads will begin and will open in the summer of 2005.

meaning the HOV lane will connect to the stretch going by the airport but not the downtown area. A ramp from the westbound I-10 HOV lane will connect to the northbound Arizona 51 HOV lane. At Shea, the HOV lanes will merge into the freeway, as the heavier traffic is between Interstate 10 and Shea, Burdick said.

ADOT is hearing from drivers and neighbors that the new rubberized asphalt results in a quieter freeway.

Rubber meets the road

Rubberized asphalt is made of a mixture of oil compounds and ground-up old tires. About 1,500 tires go into the mix that covers one lane for one mile, so one mile of three lanes of freeway in each direction uses about 9,000 old tires.

Burdick said that ADOT engineers have determined that newly laid rubberized asphalt is about 3 to 5 decibels quieter than concrete. That's because the asphalt is porous and soaks up noise.

"But what we don't know is what will happen as oil from cars and dust fills in the asphalt," Burdick said.

"It's a surface that holds a lot of promise, but to make use of it widespread and take credit for noise reduction, we need to show it's going to give us a minimum of a 4-decibel reduction for years," he said.

The rubberized asphalt is put down not just for noise reduction. Burdick said, but to preserve the concrete beneath it. It costs about $380,000 per mile to put down the asphalt on each side of the freeway.

The Arizona Republic
December 12, 2002
Asphalt to muffle din from freeways

Rubberized surface slated for sections of loops 101, 202

By JOHN YANTIS
Tribune

State highway authorities are expected to announce today plans to resurface a majority of the Valley's freeway system with rubberized asphalt to reduce the amount of traffic noise bombarding neighborhoods.

Outgoing Gov. Jane Hull and Arizona Department of Transportation director Victor Mendez will announce the plan at a 2 p.m. news conference, officials said.

The news should please East Valley residents along the newest stretches of loops 101 and 202, many of whom have attended about a dozen community meetings in an effort to lessen the freeways' effects.

"The governor's unveiling a plan that ADOT has worked out with the Maricopa Association of Governments over the last three months to use rubberized asphalt on a majority of the Valley's freeway program," said John Carlson, Hull's transportation policy adviser. "It's really good news."

ADOT spokesman Doug Nintzel would not confirm or deny the information.

"We've been working for a long time to respond to the concerns raised by local residents," he said. "We think
FREeways: New service called ‘a benefit for everybody’

FROM PAGE A1

we’re taking a step in the right direction.”

Rep. Laura Knaperek, R-Tempe, and Tempe City Councilwoman Barb Carter, who have met with residents over the issue, confirmed that repaving will be done.

“There has been a great effort on behalf of the governor, ADOT and even the mayors to make sure that rubberized asphalt happens, because that’s what the community wants, that’s what the neighborhoods want,” Knaperek said. “I do know this is the right thing to do, and I’m glad that it’s happening at this particular point in time because it does affect people’s quality of life and their property values. It’s a benefit for everybody, and we get rid of the tires on top of it all.”

Because of the estimated cost — $500,000 a mile — ADOT has been reluctant to cover the white cement of freeways with an inch-thick layer of black rubberized asphalt made from used tires. While a two-mile stretch of Loop 101 near McCormick Ranch in Scottsdale was recently repaved, other neighborhoods — some in Tempe and Mesa — wanting the same treatment have been going without while the agency argues it does not have the money to resurface the entire freeway system.

“ADOT is really sick of going to neighborhood meetings and listening to neighbors complain,” Carter said.

The agency has been criticized repeatedly for taking false noise measurements in areas clamoring for help. ADOT defended its tests and said it could not coat sections of highway since the asphalt is not recognized by the federal government as a noise reduction measure because there isn’t enough research on the material’s long-term sound-reducing qualities.

Recently, a 13-mile stretch of U.S. 60 was widened and coated with the substance.

The product offers many advantages, officials said. Besides reducing noise, offering a smoother surface and saving thousands of tires from landfills, rubberized asphalt protects the original road and lasts longer than regular asphalt before needing routine maintenance, officials contend.

While it’s unclear where funding will come from, Knaperek and Carlson said the plan will not hurt the timing of future freeway projects.

CONTACT WRITER: (480) 970-2345
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Noise reduction on road is clear

Regarding Thursday's front-page article “Freeway noise reduction plan hits snag”:

As I travel U.S. 60 and come upon the portion of the highway that is composed of rubberized asphalt, there is an immediate reduction of noise in my automobile. There is no question that this process reduces noise.

My suggestion to the Arizona Department of Transportation is to do a video with sound for the Federal Highway Administration to help show how much this process reduces noise.

— Mike Terrill
Mesa
Hear that? No? Good

Our stand: Driving U.S. 60 or 101 silences critics of new asphalt

Shhh: Let's whisper. Hooray for quiet freeways! And hooray for state and local officials, who put together a project to pave 115 miles of freeway with noise-absorbing rubberized asphalt.

This was a bold move and the right move, especially in tight budget times.

Skeptical? Take a drive on U.S. 60 through Mesa and Tempe. Or check out Loop 101 as it goes by McCormick Ranch.

Suddenly, the traffic roar drops, and you don't need the radio turned up full blast. Neighbors have regained some peace and quiet.

In both spots, the Arizona Department of Transportation applied a coat of asphalt that includes bits of shredded recycled tires. Three-fourths of the din from traffic comes from the sound of tires rolling over the road surface. This special asphalt reduces the noise at its source.

It's a lot like dealing with a kid with a blaring CD player in the bedroom. To reduce the noise, you can either shut the door (the equivalent of building sound walls) or turn down the volume (which would be like laying rubberized asphalt).

Quieter freeways aren't a frivolous luxury. Noise degrades our quality of life and damages our health. Hikers seeking peace in places like Squaw Peak Park find that freeway noise echoes through the canyons.

Research shows children don't do as well in school if they live in noisy neighborhoods. Noise aggravates all sorts of stress-related ills. It's not a stretch to speculate that drivers might be more attentive and less prone to aggressive behavior in a quieter car.

Don't be distracted by two phony issues: cost and effectiveness.

The tab for the resurfacing is $34 million. But that's over three years. ADOT and the Maricopa Association of Governments managed to come up with the money without shortchanging other projects. It involved a little juggling of priorities and tapping money that had not yet been earmarked.

As for effectiveness, we repeat: Just drive it.

The problem is that federal transportation policy doesn't recognize surface treatments as a way to reduce noise. For funding and environmental purposes, the approved strategies are sound walls and berms.

But thanks to Arizona's track record with rubberized asphalt, which ADOT has used since 1988, the Federal Highway Administration has tentatively approved a pilot project here to study its noise-reduction potential. That could eventually lead to a change in federal policy.

We're smart not to wait. Studies already show rubberized asphalt works. Sacramento County found that over a six-year period, it reduced traffic noise on an expressway by 4 decibels — that translates to 60 percent less noise.

Sacramento now uses rubberized asphalt on most road projects. And not just for noise. The asphalt forms a protective layer that reduces pavement cracking and potholes, cutting down on maintenance work.

We also get an environmental boost from disposing of millions of old tires, which otherwise can bum in nasty, polluting fires that are hard to put out.

An Arizonan, Charles McDonald, pioneered in the technique of mixing bits of tire into asphalt in the 1960s. What a wonderfully ambitious step to use it around the Valley.

The Maricopa Association of Governments and the State Transportation Board still need to sign off on the proposal. If their members have any doubts, there's one way to settle the question: Drive the freeways and listen.
101 paving plan halts noise uproar

By Lesley Wight
Scottsdale Republic
Thrusday, January 2, 2003

101 paving plan halts noise uproar

A $34 million Valley-wide rubberized asphalt pilot project will test how long the surface's noise-reducing effects last.

Coming Friday

101 paving plan halts noise uproar

The Arizona Republic, Thursday, January 2, 2003
Council ready to OK 101 repaving

Will speed plans to quiet freeway

By Lesley Wright
Scottsdale Republic

SCOTTSDALE — It may still be crowded, dangerous and a magnet for crazed drivers, but the Loop 101 freeway will be much quieter for its Scottsdale neighbors by this time next year.

The Scottsdale City Council will vote Monday on a deal with the Arizona Department of Transportation to hurry the repaving of Scottsdale’s 16 miles of Loop 101 with noise-dampening rubberized asphalt.

The state originally planned to do the work in 2005 and 2006.

Council members are expected to approve a plan to front $3.9 million to ADOT so Scottsdale can be at the head of the line for the Valley-wide project. Phoenix also is advancing the cash for a speedy paving schedule.

The state transportation agency then will repay the city in the years when the work was originally scheduled — 2005 and 2006.

Each mile of the repaving project will cost an estimated $325,000.
The Arizona Republic, Saturday, May 31, 2003

LOOP Funds to quiet traffic on freeway

From Page 1

Highway Administration decided last fall to take another look at rubberized asphalt. Previously, the federal government did not recognize the material’s use for hushing traffic.

As a result, ADOT officials decided to repave nearly 90 miles of the concrete freeway, but needed some cash up front from cities to do it quickly. ADOT will eventually receive the federal funds and repay the cities.

The repaving of Loop 101 in Scottsdale will be done in segments:

- September 2003: Frank Lloyd Wright Boulevard south to Raintree Drive.
- March 2004: 90th Street/Pima Road south to McKellips Road.
- September 2004: Frank Lloyd Wright west to Scottsdale Road.

The segment between 90th Street/Pima Road and Raintree Drive was repaved with rubberized asphalt this past winter.

Reach the reporter at lesley.wright@scottsdalerepublic.com or (602) 444-6883.
Workers confer Thursday at a construction site on the Interstate 10 bridge that will go over Washington and Jefferson streets in Phoenix. Their efforts will make life easier for Valley motorists.

Major revamp to add lanes, access and quiet

By Bob戈fien
The Arizona Republic

Drivers are learning the lesson: avoid Arizona 51 on the weekends.

Nearly every Saturday and Sunday since March 31, sections of the Phoenix freeway have been closed or jammed with bottlenecked traffic while construction crews perform the monumental job of widening and improving the road.

Everything about Arizona 51 is changing. The name has been switched from Squaw Peak...
The Arizona Republic
October 11, 2003

Joy said the rapid pace of the project and the efforts to keep traffic moving will have no negative effect on the quality of the project.

"We're trying to build this project as good as we can in as short a time as we can with as little inconvenience as we can," Joy said. "And in the end, people will call it all worthwhile; that's what I'm shooting for."

The project has been divided into three segments, each with its own project manager and ADOT crew. From the south, the sections are from I-10 near Sky Harbor International Airport to McDowell Road; McDowell Road to Glendale Avenue; and Glendale Avenue to Shea Boulevard.

Complicated work
The biggest snarl has been around the junction between S1, I-10 and Loop 202 near the airport. At this transitional area, ADOT workers are linking a complex system of "braided" ramps to smooth out traffic movement. New bridges for HOV lanes, general widening and a new link between westbound I-10 and Arizona 51 are highlights. The middle segment consists of widening the road to add lanes with HOV access, plus new drainage systems and sound barriers. The northern segment is mainly the completion of HOV lanes in the open center median.

Complaints about the project have come mostly from neighbors who complain about noise, said Marc Della Rocca, a community relations specialist for the project. Motorists have griped about the 45-mph speed limit through the long construction area.

Walls raise concerns
There also has been aesthetic concerns about the sound walls that are being added or increased in height because they block the view for motorists and some neighbors. ADOT did a comprehensive study along the corridor to determine where to put sound walls, Burdick said, and made decisions based on the study and surveys of nearby residents.

"Sound mitigation has a bigger impact (on design priorities) than the view," Wade said.

The sound barriers will appear less intrusive as the project is completed, he added, with a wide shoulder lane moving traffic away from the walls.

About 14 miles of sound walls is being added or raised, with a target noise level of about 67 decibels outside the freeway right of way. A normal conversation registers about 64 decibels, Burdick said.

Public input has been an important part of this project, Della Rocca said, with an SRSL.com Web site, e-mail access, newsletters and a 24-hour hotline.

Airport little affected
Traffic to and from the Sky Harbor has been only mildly affected by construction, airport spokeswoman Jeanne L'Ecyer said.

"People are planning more time for their commute," L'Ecyer said about the thousands of airport workers. "By and large, folks around here are just anxious to see it finished."

Drivers could be inconvenienced more in coming months, Joy said, as road work moves from night to day and more work is done to create lanes and build the median. Part of the congestion is the effect of drivers rubbernecking to see the work, Joy said.
The Arizona Republic, October 11, 2003

**Freeway construction**

The finished ramp project at Interstate 10 and Arizona 51 will add HOV lanes and simplify traffic patterns in the busy area.

- New road
- HOV lanes median

**Rubberized asphalt: A few quick facts**

- Rubberized asphalt is a paving material made of regular asphalt mixed with ground-up used tires.
- It was designed to eliminate an environmental problem: hundreds of thousands of used tires piling up in landfills and recycling yards.
- It's more durable than regular asphalt, lasting about 10 years in the Phoenix area.
- It's cheaper and easier to replace than concrete, and motorists and freeway neighbors favor the smooth surface for noise reduction.
- About 1,500 used tires go into every mile of paving.
- Twenty-one miles of Loop 101 and Arizona 51 are being paved with rubberized asphalt.
- Rubberized-asphalt paving is a warm-weather occupation because the underlying concrete surface must be warm so the paving will adhere. ADOT expects to end this year’s projects by Nov. 15 and begin again in the spring, including paving the rebuilt Arizona 51.

— Bob戈fen