NEVADA DOT TIRE/PAVEMENT NOISE STUDY

By:

Douglas I. Hanson
Assistant Director
National Center for Asphalt Technology
Auburn University, Auburn, Alabama

Robert S. James
Civil Engineer
National Center for Asphalt Technology
Auburn University, Auburn, Alabama

Sponsored by

Nevada Department of Transportation
Carson City, Nevada

September 2004

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Nevada Department of Transportation or the National Center for Asphalt Technology. This report does not constitute a standard, specification or regulation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

In today's society, traffic noise is a serious problem. The term "noise" should not be confused with the term sound. Noise is the generation of sounds that are unwanted. With respect to traffic, noise would be the generation of sounds that affect the quality of life for persons near roadways. Therefore, traffic noise can be considered an environmental pollution because it lowers the standard of living. Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will reduce the level of noise generated on roadways. This paper provides the results of testing to define the noise levels of selected highway sections in the vicinity of Las Vegas, NV. The study concluded that the OGFC pavement being used by the Nevada DOT will provide the citizens of Nevada with a low-noise pavement surface.

Nevada DOT Pavement/Tire Noise Study

Douglas I. Hanson, Robert S. James

INTRODUCTION

Background

Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will provide low noise roadways. The National Center for Asphalt Technology (NCAT) has initiated a study to develop a pavement selection guide or design manual for use by the DOTs and others to design low noise Hot Mix Asphalt (HMA) pavement wearing courses.

Throughout the world, sound caused by transportation systems is the number one noise complaint. Highway noise is one of the prime offenders. Engine (power train), exhaust, aerodynamic and pavement/tire noise all contribute to traffic noise.

In the United States, the Federal Highway Administration has published the noise standards for highway projects as 23CFR772(*1*). The FHWA Noise Abatement Criteria states that noise mitigation must be considered for residential areas when the A-weighted sound pressure levels approach or exceed 67 dB (A). To accomplish this, many areas in the United States are building large sound barrier walls at a cost of one to five million dollars per roadway mile. Noise barriers are the most common abatement strategy. The FHWA reports that the DOTs through 1998 have spent over 1.4 billion dollars on walls for noise control (*1*). At the time this report was written, these walls cost up to 5 million dollars per mile in California. Also, other strategies such as alterations of horizontal/vertical alignment, traffic controls, greenbelts and insulation of structures are used to reduce noise. Each of these noise reduction measures can add significant cost to a project. In addition, each is limited in the amount of noise reduction that is possible and in many cases cannot be used for practical reasons. For example, noise barriers cannot be used if driveways are present.

It has been shown that modification of pavement surface type and/or texture can result in significant tire/pavement noise reductions. European highway agencies have found that the proper selection of the pavement surface can be an appropriate noise abatement procedure. Specifically, they have identified that a low noise road surface can be built at the same time considering safety, durability and cost using one of the following approaches (*2*):

1. A surface with a smooth surface texture using small maximum size aggregate
2. A porous surface, such as an open graded friction course (OGFC) with a high air void content
3. A pavement-wearing surface with an inherent low stiffness at the tire/pavement interface.

Purpose and Scope

The purpose of this paper is to present the results of noise testing accomplished by the National Center for Asphalt Technology using a Close-proximity noise trailer. The paper discusses the nature of tire/pavement noise and the results of testing selected pavements in Nevada.

NATURE OF NOISE

Noise is defined as "unwanted sound". Different people have different perceptions of what sound they like and what sound they don't like. The roar of the crowd at a baseball game or the laughter of children would commonly be considered pleasant sounds while the sound of a lawnmower or garbage truck would be considered noise or unwanted sound (*3*).

Noise like all other sounds is a form of acoustic energy. It differs from pleasant sounds only in the fact that it often disturbs us and has the characteristics of an uninvited guest. To understand noise or sound requires an understanding of the physics of sound and how humans respond to it.

Sound is acoustic energy or sound pressure that is measured in decibels. The decibel combines the magnitude of sound with how humans hear. Since human hearing covers such a large range of sounds, it does not lend itself to be measured with a linear scale. If a linear scale was used to measure all sounds that could be heard by the human ear, most sounds (assuming a linear scale of 0 to 1) occurring in daily life would be recorded between 0.0 and 0.01. Thus, it would be difficult to discriminate between sound levels in our daily lives on a linear scale.

Instead of a linear scale, a logarithmic scale is used to represent sound levels and the unit is called a decibel or dB. The A-scale is used to describe noise. The term dB(A) is used when referring to the A-scale. The curve that describes the A-scale roughly corresponds to the response of the human ear to sound. Studies have shown that when people make judgments about how noisy a source is that their judgments correspond quite well to the A-scale sound levels. It refers to the loudness that a human ear would perceive. It, in effect, is a dB corrected to account for human hearing. The ear has its own filtering mechanisms and the inclusion of the A after dB indicates that the scale has been adjusted or "fine tuned" to hear like a human. Thus, a noise level of 85 dB(A) from a noise source would be judged louder or more annoying than a noise level of 82 dB(A). The decibel (A-weighted) scale ranges from 0 dB(A), the threshold of human hearing, to 140 dB(A) where serious hearing damage can occur. Table 1 (*3*) represents this scale and some of the levels associated with various daily activities.

Table 1 – Noise Levels Associated with Common Activities (*3*)

Activity	Noise Level (dB(A)
Lawnmower	95
Loud Shout	90
Motorcycle passing 50 feet away	85
Blender at 3 feet	85
Car traveling 60 mph passing 50 feet away	80
Normal conversation	60
Quiet Living room	40

A serene farm setting might have a decibel level of 30 dB(A) while a peaceful subdivision might be at 40 to 50 dB(A). Alongside a freeway the sound level (i.e. noise) might be in the range of 70 to 80 dB(A). The transition from a peaceful environment to a noisy environment is around 50 to 70 dB(A). Sustained exposure to noise levels in excess of 65 dB(A) can have negative health effects. As a general rule of thumb, one can only differentiate between two sound levels that are at least 3 dB(A) different in loudness.

In addition to sound level, people hear over a range of frequencies (and this is the reason for the A weighting described earlier). A person with good hearing can typically hear frequencies between 20 Hz and 20,000 Hz. An older person, however, may not be able to hear frequencies above 5,000 Hz. So this indicates, to some extent, some of the reasons why different people hear things somewhat differently.

Addition of Noise Levels

Noise levels are measured on a logarithmic scale. Therefore, when combining the effect of multiple sources this must be considered. The formula used to combine multiple sources of sound is (*3*):

$$dB(A)_t = 10 * \log [10^{\{dB(A)_1/10\}} + 10^{\{dB(A)_2/10\}} + ... + 10^{\{dB(A)_n/10\}}]$$

Figure 1 illustrates the effects of adding two point source noise levels. If the sound level from one source of sound (a blender) measured at three feet from the blender is 85 dB(A) (from Table 1), then the sound level from two blenders would be 88 dB(A) and the sound level from three blenders would 89.8 dB(A). Therefore, doubling the sound emissions would result in a 3 dB(A) increase in noise levels. This can be determined for any number of sound sources by using the above equation. For roadway surfaces this means that if the number of vehicles in the traffic flow is doubled, the sound level will increase by 3 dB(A) (*3*).

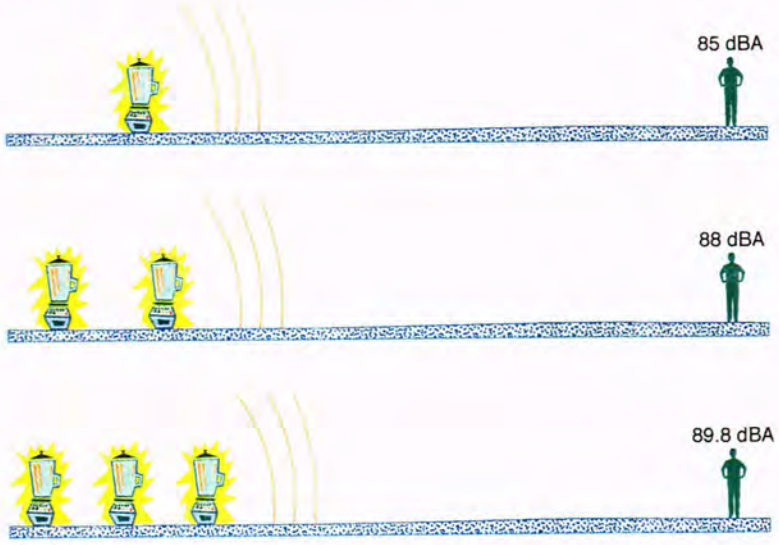


Figure 1 – Effect of Adding Noise Sources

Propagation of Noise from a Point Source

An important mitigating factor with regard to noise is the distance between the source and the receiver. Sound levels decrease in accordance to the inverse-square law. This law is a fundamental law of acoustics – it states that the sound varies inversely as the square of the distance. As the distance increases, the noise levels decrease. For a point source, such as a blender the attenuation factor is 6 dB (A) when the distance away from the source is doubled and is 9.5 dB (A) at three times the distance. Thus, again if you have a blender that has a sound level of 85 dB (A) at three feet then when you move six feet away from the blender the noise level would be 79 dB (A) and if you move three times the distance (9 feet) away from the blender the noise level would be 75.5 dB (A). This is illustrated in Figure 2.

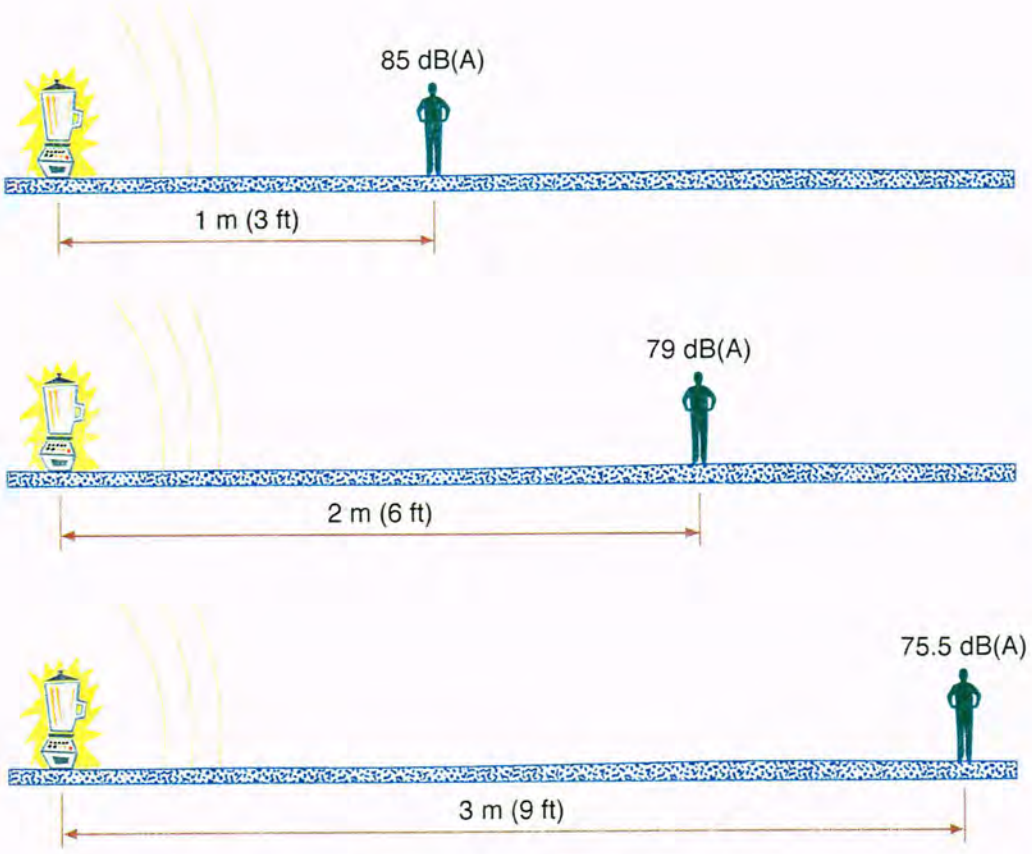


Figure 2 – Effect of Distance on a Point Noise Source

Propagation of Traffic Noise

Roadway noise acts in a different manner. Roadway noise is classified as a line source since noise is transmitted along the entire length of the roadway (*3*). As a vehicle passes by a point, the noise is reaching the point from all along the roadway, or from each point where the vehicle was. As the distance from the source increases, the noise level decreases at a lower rate than from a single point noise source. For paved surfaces, the doubling of the distance would result in a 3 dB (A) reduction in the noise level. Thus, if a point 16 feet from the center of the noise source (the center of the lane) of the roadway has a noise level of 85 dB (A), then a point 32 feet from the center of the noise source would have a noise level of 82 dB (A). This is illustrated in Figure 3.

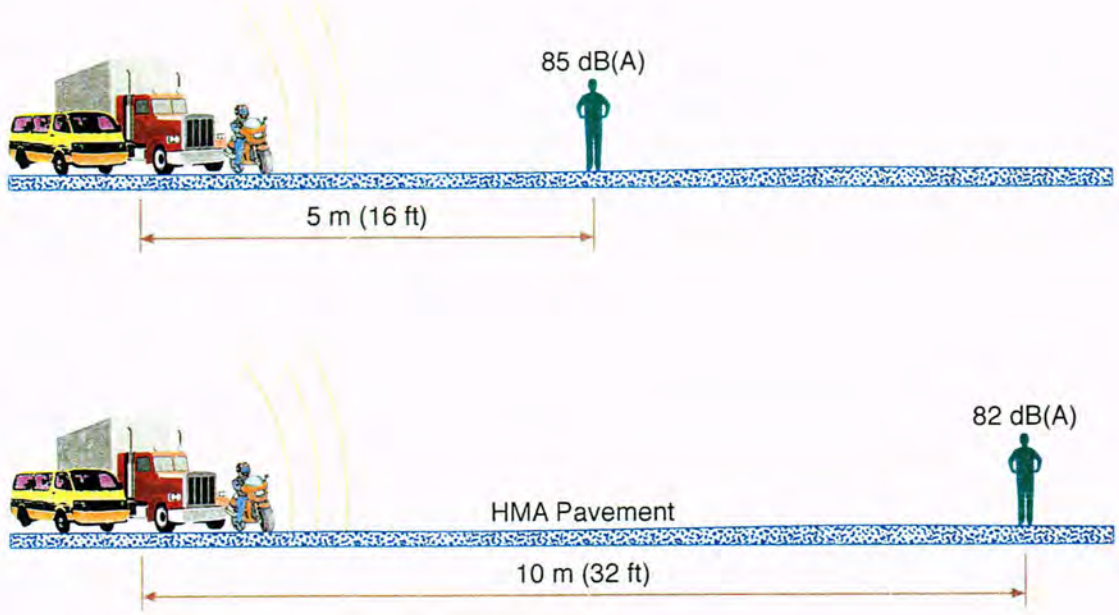


Figure 3 – Effect of Distance on a Line Noise Source Over a Paved Surface

The noise level near the road not only depends on the noise being generated by the traffic but, also the characteristics of the ground adjacent to the road. The Traffic Noise Model used by the Federal Highway Administration (*3*) to predict noise levels along side the roadway uses the following equation to approximate the drop off:

$$\text{Distance Adjustments dB(A)} = 10 * \log_{10}\{(d_2/d_1)^{1+\alpha}\}$$

where: α = attenuation coefficient which is
0.0 for hard ground or pavement
0.5 for soft ground

d_1 , d_2 = distance from roadway centerline

Thus, if the noise level is 85 dB(A) at the edge of pavement which is at 16 feet (1/2 of a 12 foot lane plus a ten foot shoulder) from the center of the noise source and the man is 200 feet from the roadway edge with soft ground between the roadway edge and the man this equation would predict that the noise level would be 68.5 dB(A) at the man. This is illustrated in Figure 4. In a rural situation, where the ground between the roadway edge and the receiver is soft and covered with vegetation the noise level would be further reduced due to absorption of the sound into the ground.

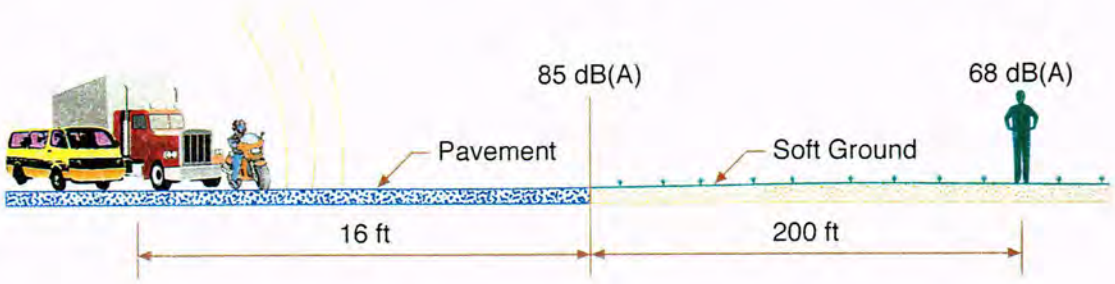


Figure 4 – Effect of Distance on a Line Noise Source
Sound Traveling Over Soft Ground

FIELD MEASUREMENT OF ROAD NOISE

A standardized method for the measurement of noise is necessary to allow the pavement engineer to characterize the level of the noise from different pavement wearing courses. Considerable work has been done to develop such techniques. Three methods commonly used for measuring pavement noise levels in the field are:

1. The statistical pass-by procedures as defined by both International Standards Organization (ISO) Standard 11819-1 (*5*) and the FHWA manual Measurement of Highway-Related Noise (*6*)
2. The single vehicle pass-by method (*6*)
3. The near-field techniques such as the close proximity method (CPX) that was developed in Europe and is defined by ISO Standard 11819-2. (*7*)

Statistical Pass-by Methods

The statistical pass-by method consists of placing microphones at a defined distance from the vehicle path at the side of the roadway. In Europe, the ISO Standard 11819-1 calls for placing microphones 25 feet from the center of the vehicle lane at a height of 4 feet above the pavement. It also requires that the noise characteristics and speed of 180 vehicles be obtained (100 automobiles and 80 dual-axle and multi-axle trucks). This data is then analyzed to determine the statistical pass-by index (SPBI) (*6*).

The FHWA procedure developed by the Volpe Transportation Systems Center (*6*) calls for the placement of a microphone or microphones 50 feet (instead of 25 feet) from the center of the travel lane. The ground surface within the measurement area must be representative of

acoustically hard terrain, the site must be located away from known noise surfaces, and is to exhibit constant-speed roadway traffic operating under cruise conditions. The FHWA procedure does not specifically state the number of vehicles required for a valid sample. It states that the number of samples is somewhat arbitrary and is often a function of budgetary limitations. But, the procedure does provide some guidance. For example if the traffic speed is 51 to 60 mph the minimum number of samples recommended is 200.

Both of these pass-by methods are time consuming to conduct. The results vary based on the traffic mix (even if the vehicle types are the same the differences in tires can cause problems). The testing conditions that must be met to conduct these measurements are very restrictive. The roadway must be essentially straight and level, there is a limit on the background noise, no acoustically reflective surfaces can be within 30 feet of the microphone position, and the traffic must be moving at a relatively uniform speed. The result of these restrictions is that a limited number of pavement surfaces can be tested economically.

Single Vehicle Pass-by or Controlled Pass-by Method

In the single vehicle pass-by method, noise from cars and light trucks is typically measured at a specially designed test site. The vehicle approaches the site at a specified speed in a specified gear. There are no national standards for this type of testing. An example of this type of testing is a study conducted by Marquette University for the Wisconsin DOT (*8*). In this study, they used a 1996 Ford Taurus that was operated at 60, 65 and 70 mph in the right lane. They conducted their testing by placing two microphones five feet above the pavement and positioned at 25 feet from the center of the traffic lane. The microphones were placed two hundred feet apart. Three runs were made to collect enough data for each speed.

Another method (*8*) to conduct this testing is to conduct the testing on an accelerating vehicle. In this procedure at the entrance to a "trap" section of the test site, the vehicle begins to accelerate at full throttle. A sound level meter is set at a specified distance from the center of the travel path of the vehicle and is used to capture the maximum sound level of the vehicle as it passes through the "trap". This procedure tends to emphasize power train noise since the vehicle is in full acceleration during the test.

Close-Proximity Method (CPX) or Near-field Measurements

Near-field tire/pavement noise consists of measuring the sound levels at or near the tire/pavement interface. In the CPX method, sound pressure is measured using microphones located near the road surface.

The requirements for the CPX trailer are described in ISO Standard 11819-2 (*7*). This method consists of placing microphones near the tire/pavement interface to directly measure tire/pavement noise levels. In 2002, NCAT built two CPX trailers, one for the Arizona Department of Transportation and one for use by NCAT. A picture of the NCAT trailer is shown in Figure 5.

Figure 5 – NCAT Close Proximity Trailer

The ISO Standard calls for the measurement of sound pressure and the microphones at eight inches from the center of the tire and four inches above the surface of the pavement. The microphones are mounted inside an acoustical chamber to isolate the sound from passing traffic. The acoustical chamber is required because sound pressure microphones will measure the sound from all directions and thus, there is a need to isolate the sound from other traffic and sound reflective surfaces. Figure 6 shows the mounting of the microphones and the acoustical chamber

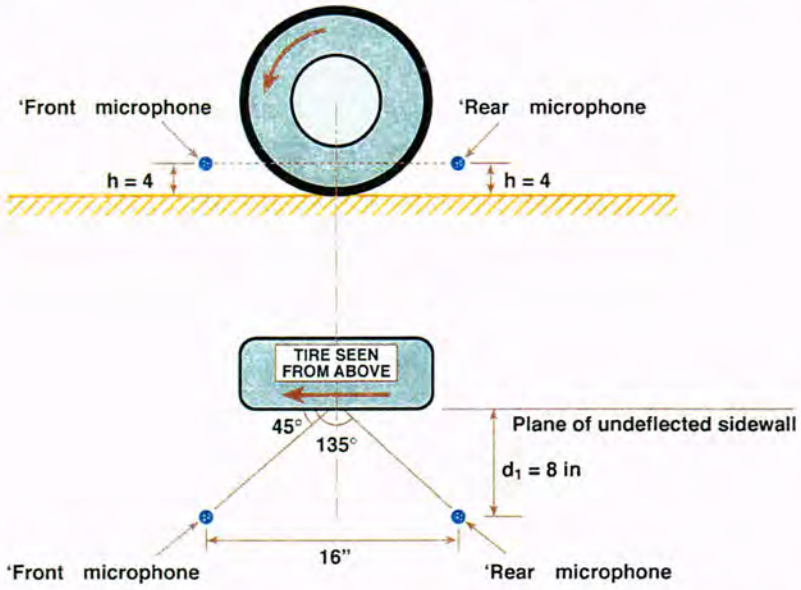


Figure 6 – Diagram Showing Microphone Locations in NCAT CPX Trailer

A concern with regard to the use of near-field measurements is that they measure only the tire/pavement noise component of traffic related noise (*2*). The standard method used by the FHWA's Volpe Laboratories for measuring traffic noise for use with the FHWA's traffic noise model is the statistical pass-by method. This method was selected because it includes both the power train and tire/pavement noise. Both the power train and tire/pavement noise are strongly related to vehicle speed. At low speeds power train noise dominates while at high speeds tire/pavement noise dominates. As was discussed earlier, work done in Europe has indicated that there is a crossover speed for constant-speed driving of about 25 to 30 mph for cars and about 35 to 45 mph for trucks (*2*). At speeds less than 25 to 30 mph for cars or 35 to 45 mph for trucks, the power train noise dominates; however, at higher speeds the tire/pavement noise is more prevalent. Therefore, it appears that the concept of measuring the noise level of roadways at the tire/pavement interface is valid for roadways having speed limits above 45 mph.

The near-field test procedures offer many advantages:

1. The ability to determine the noise characteristics of the road surface at almost any arbitrary site.
2. It could be used for checking compliance with a noise specification for a surface.
3. It could be used to check the state of maintenance, i.e. the wear or damage to the surface, as well as clogging and the effect of cleaning porous surfaces.
4. It is much more portable than the pass-by methods, requiring little setup prior to use.

SUMMARY OF RESULTS FROM OTHER NCAT NOISE TESTING

NCAT has now tested approximately 244 pavement surfaces in ten states. This includes 201 Hot Mix Asphalt (HMA) surfaces that include different Superpave gradations, microsurfacing, NovaChip, Stone Matrix Asphalt (SMA) and OGFC surfaces. Forty-three Portland Cement Concrete Pavement (PCCP) surfaces have been tested. The following are average values from that testing (only test sections of at least one-mile in length are included in these averages):

1. HMA Pavements

    a. Open-graded (fine gradation) mixes - 93 bB(A)
    b. Dense graded HMA - 95 dB(A).
    c. Stone Matrix Asphalt Mixes - 96 dB(A).
    d. Open-graded (coarse gradation) mixes - 97 dB(A).
    e. Average variability over a one-mile section - 3.8 dB(A)

2. PCCP pavements:

    a. Diamond Ground – 98.1 dB(A)
    b. Longitudinally tined – 98.8 dB(A)
    c. Longitudinally grooved – 101.6 dB(A)
    d. Transverse tined – 102.6 dB(A)
    e. Average variability over a one-mile pavement section – 4.4 dB(A)

The results presented above are representative of values reported with a CPX trailer in Europe. There is no official definition of what constitutes a quiet pavement. Dr Sandberg in his book *(2)* defines "A *low noise road surface* as a road surface which, when interacting with a rolling tyre, influences vehicle noise in such a way as to cause at least than that obtained on conventional and *most common* road surfaces." The most common road surface in the United States is HMA, approximately 92% of the pavement surfaces are HMA. Thus if the most common" road surface is a dense graded HMA, it could be concluded that a "low noise road surface" would be a surface that has a noise level of about 92 dB(A) when measured with a CPX trailer.

TEST RESULTS

In October 2003 the National Center for Asphalt Technology tested ten pavement surfaces in the Las Vegas area at the request of the Nevada DOT. The sections to be tested were chosen by the Nevada DOT. Figure 7 shows the locations of each of the sections and Table 2 presents a summary of the data from the testing.

Figure 7 – Map Showing Test Locations

Table 2 – Summary of Nevada Test Data

Site No.	Route & Direction	Lane No. Tested	Mix Type of Surface	Age (yrs.)	Milepost		Noise Level dB(A)		Average Both Tire Types dB(A)
					Fm	To	Aqua-tred	Uni-royal	
1	I 15 S	3	OGFC	1	12.0	11.0	93.8	93.6	93.7
2	US 95 N	1	OGFC	2	108.0	109.0	93.6	93.7	93.7
3	US 95 N	1	OGFC	8	119.9	120.8	93.8	93.9	93.8
4	SR 160 W	1	OGFC	11	2.3	3.3	98.8	98.7	98.8
5	IR 215 Interim Frontage Road W	1	Plant Mix Bituminous Surface	3	Jones Blvd to Rainbow Blvd		98.1	97.8	98.0
6	I 15 N	3	PCCP – Longitudinal Grooving	2	40.5	41.5	99.5	98.9	99.2
7	I 15 S	3	PCCP Transverse Tined	13	21.5	20.5	105.1	104.9	105.0
8	I 15 S	1	PCCP – Longitudinal Tined	2	25.0	24.0	104.2	103.1	103.6
9	I 215 E	3	PCCP – Transverse Tined	8	10.0	9.0	102.2	102.1	102.2
10	I 215 E	3	PCCP – Longitudinal Tined	5	6.0	5.0	101.4	100.2	100.8

All testing was done at 60 mph using two tire types. Three tests were conducted with each tire type on each pavement surface. The reason for conducting the tests with two types of tire is to provide a better representation of the tire/pavement noise levels for each surface type. The two tires used were a Goodyear Aquatred and a Uniroyal Tiger Paw. Appendix A contains pictures of each tire type thus showing the tire tread pattern. Appendix B contains a picture of each of the sites, a picture of the surface texture, and a plot of the noise versus frequency spectrum (using the Aquatred tire) for each surface tested.

The results are also shown graphically in figure 8. This figure shows the results from quietest to noisiest. The quietest pavements are the newer OGFC surfaces and the noiser pavements are the PCCP pavements.

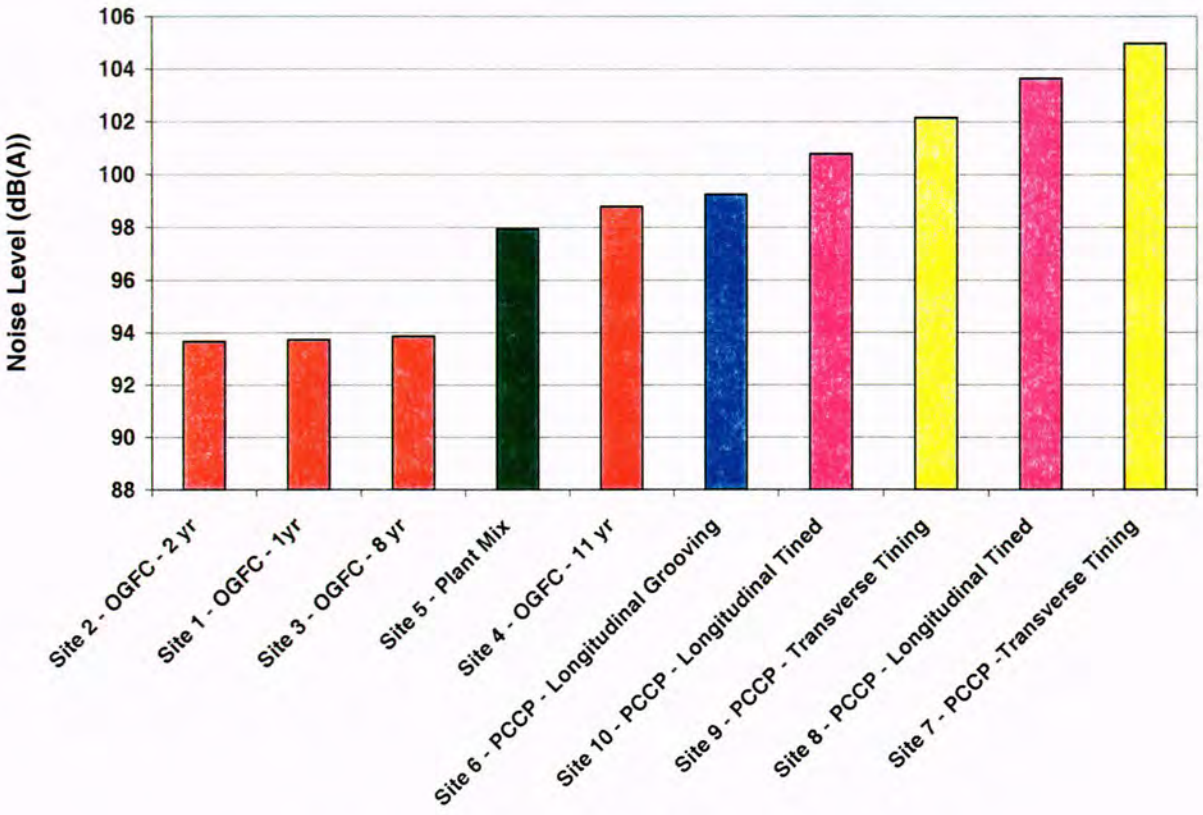


Figure 8 – Chart Comparing Pavements Tested

Discussion of HMA Test Results

Four pavements surfaced with a plant mix open-graded surface were tested, and one pavement with plant mix bituminous surface was tested. The results for the first three sites tested showed that the average noise level was 93.7 dB(A). The fourth site on SR160 was eleven years old and there was a significant increase in the noise level for this section as compared to the other three OGFC sections (from 93.7 to 98.8 dB(A) or 5.1 dB(A) which represents more than doubling of the sound pressure). The gradation specification ranges for each of the surfaces is shown in Table 3.

Table 3 – Aggregate Specification Limits for the HMA Mixes

Sieve Size	Las Vegas Paving Type 2c	OGFC – ½ inch
25 mm (1 in)	100	-
19 mm (3/4 in)	83 – 97	-
12.5 mm (1/2 in)	64 – 78	100
9.5 mm (3/8 in)	55 - 69	90 – 100
4.75 mm (No. 4)	37 - 51	35 – 55
2.36 mm (No. 8)	27 - 35	
2 mm (No 10)	-	-
1.18 mm (No. 16)	17 – 25	5- 18
(No 30)	11- 19	
0.425 mm (No. 40)	12 – 22	-
(No. 50)	-	-
0.150 mm (No. 100)	5 - 13	
0.075 mm (No. 200)	3 - 8	0 - 4

For traffic noise, it is important to consider not only the magnitude of the noise but also the frequency of the noise. Sound at low frequencies is generally less attenuated by distance than sound at high frequencies and thus propagates further from the road. The sound wave files collected in this study were analyzed using a Fourier Transform technique to produce a frequency spectrum plot. Figure 9 presents the frequency spectrum (noise (dB) versus noise frequency) for the four OGFC surfaced pavements.

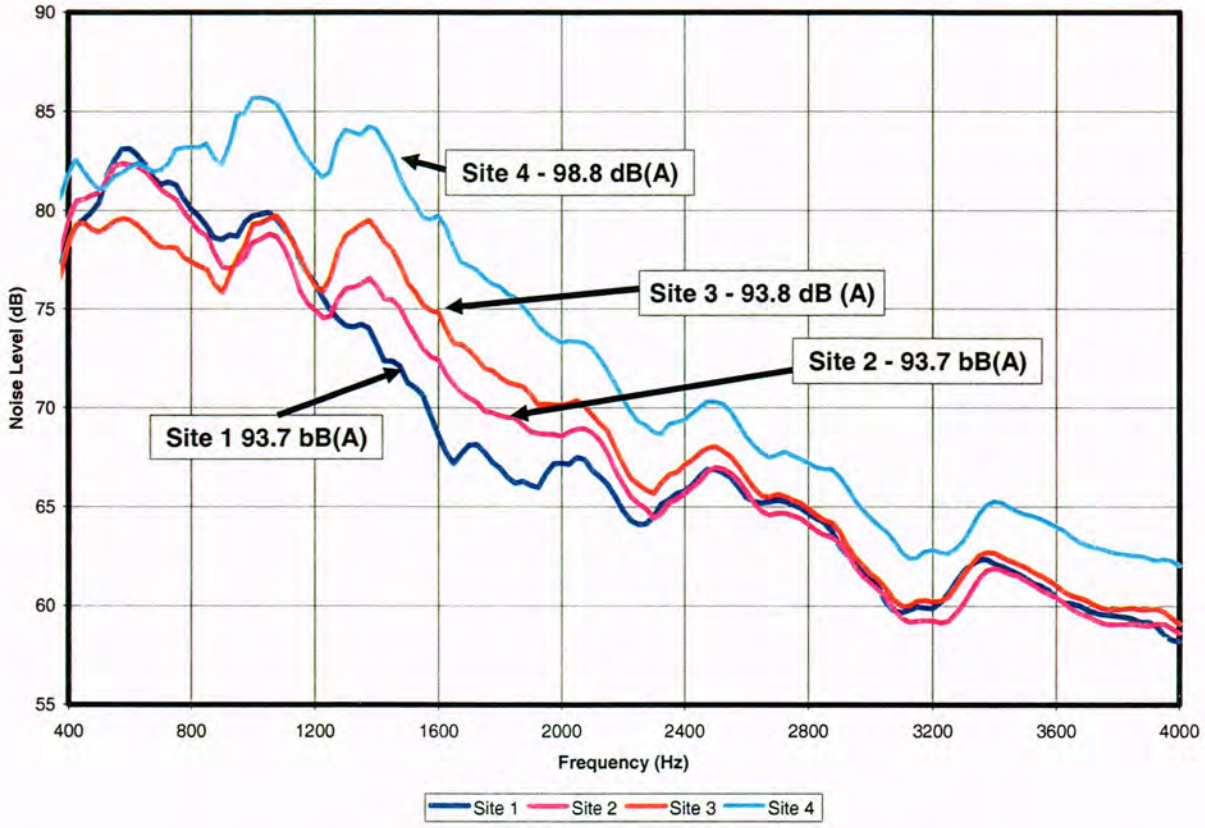


Figure 9 –Frequency Spectrum for the OGFC Surfaces

The plots in Figure 9 show that all three of the newer OGFC surfaces (sites 1, 2, & 3) have similar frequency plots. As the age of the pavement increases, the decibel level at the higher frequencies increases. Site 4 has a totally different frequency spectrum than that of the other OGFC surfaces and its noise level is much higher (about 5.1 dB(A)).

Testing on OGFC mixtures has been done primarily in three states: Alabama, Nevada and Arizona. Table 4 shows the gradations for the mixtures used in each of these states.

Table 4 – Gradations of OGFC Surfaces Tested

Gradation	Arizona	Nevada	Alabama
¾ inch	-	-	100
½ inch	-	100	89
3/8 inch	100	90 – 100	56
No. 4	38	35 – 45	14
No. 8	6	-	9
No. 16	-	5 – 18	-
No. 200	1.2	0 – 4	3.2
Average Noise Level dB(A)	91.5	93.8	98.6

It is thought that the noise characteristics of an open-graded friction course are dependent on three factors: the air voids of the mixture, the thickness of the layer, and the gradation of the mixture. It is thought that the air voids and thickness of the layer affect the high frequency component of the noise (greater than 1200 Hz.) and that the gradation affects the low frequency range (less than 800 Hz.) As air voids increase the surface becomes quieter and as the gradation becomes finer the surface becomes quieter.

Figure 10 presents a frequency spectrum for the three gradations shown in Table 4. The difference between the Nevada and Arizona mixes is a different gradation and uses a thicker surface (Arizona's thickness is one inch and the thickness for the Nevada is ¾ inch). They all have the same general shape – high noise levels at about 600 Hz, a slight peak at about 1100 Hz and then dropping off rapidly. As the mixtures become finer the peak noise at low frequency is reduced. Thus, two ways to reduce the noise level of a pavement surface would be to use a finer OGFC or increase the thickness of the OGFC layer.

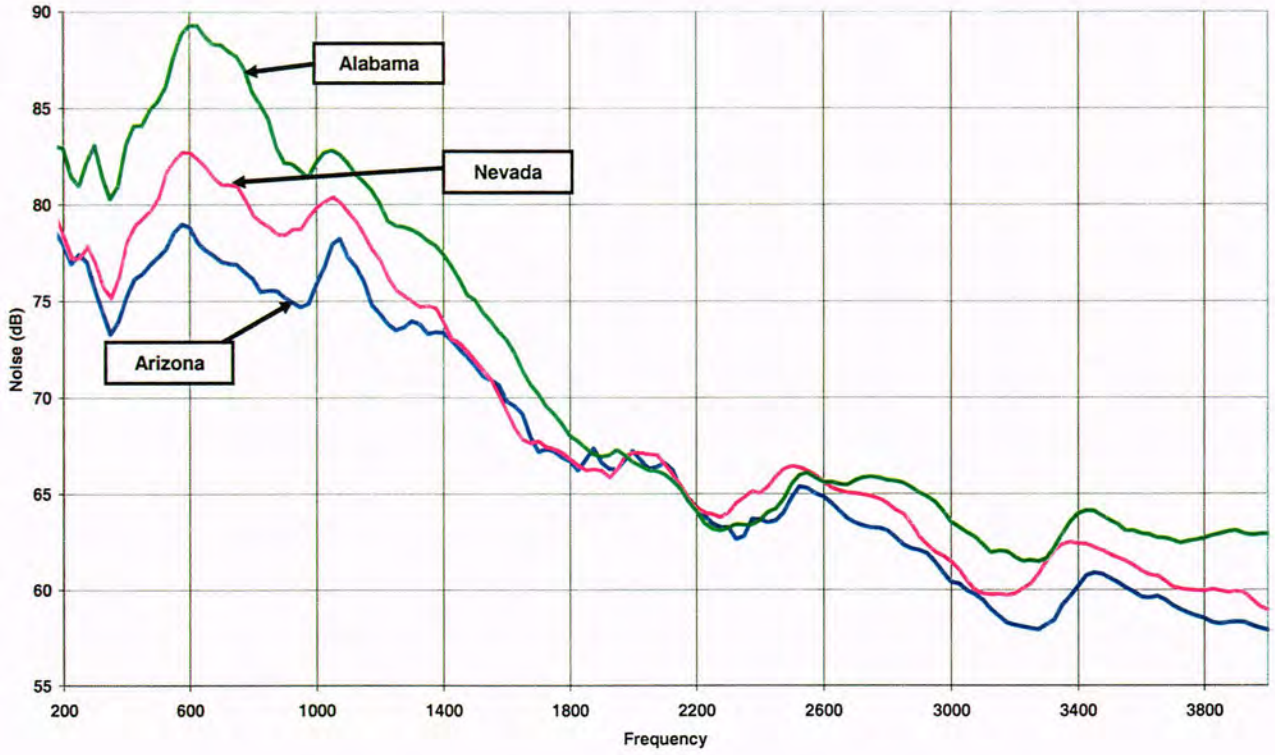


Figure 10 – Noise Spectrum for Different OGFC Mixes

Figure 11 presents the results of preliminary testing done by NCAT on different OGFC mixtures. On these sections it was possible to obtain cores and determine the in-place air voids of the surface. As can be seen as air voids increase the noise level is decreased.

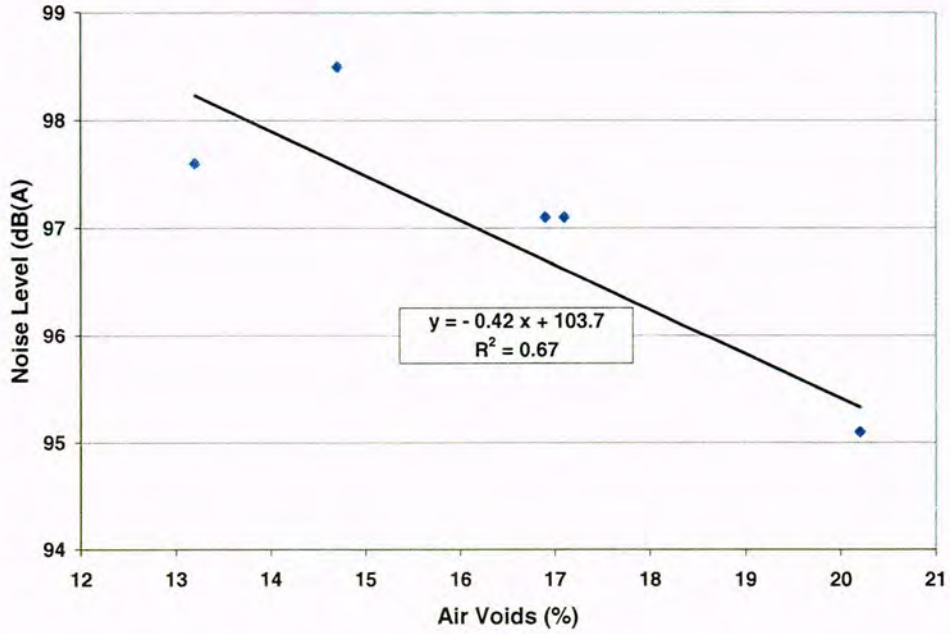


Figure 11 – Air Voids vs. Noise Level

Figure 12 shows a plot of site 4 which is an open graded friction course and site 5 the dense-graded HMA pavement. It is noted that they have similar frequency spectrums. Thus, it is hypothesized that the characteristics of site 4 have changed due to aging and filling in the surface texture with desert sands and dust. Therefore, the acoustical noise absorptive properties of an open-graded mixture have been degraded because the voids have now been filled. Therefore, the mix is now performing acoustically like a dense graded mixture.

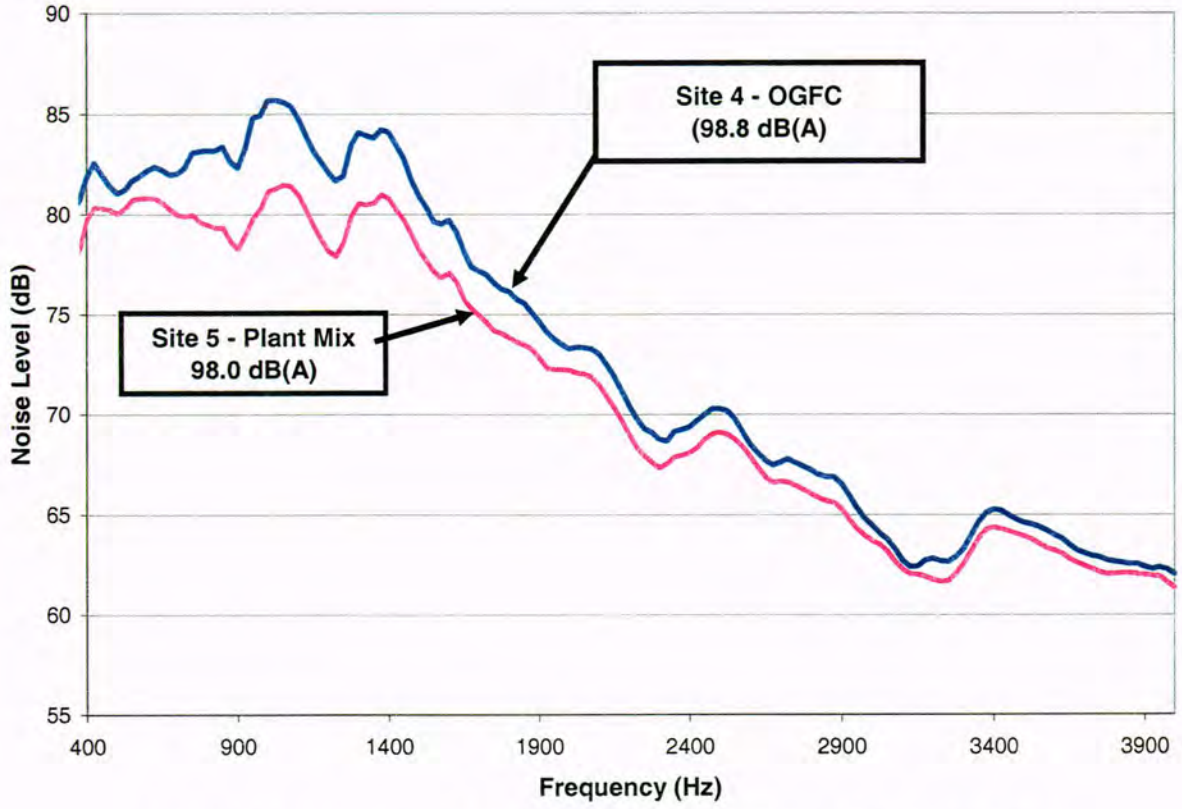


Figure 12 – Comparison of Frequency Spectrums for Sites 4 and 5

Discussion of PCCP Test Results

Five PCCP pavements were tested – two with longitudinal tining, one with longitudinal grooving, and two with transverse tining. The average noise level for the longitudinally tined PCCP was 102.2 dB(A), for the longitudinally grooved pavement it was 99.2 dB(A), and for the transversely tined pavement it was 103.6 dB(A). Figure 13 presents the frequency spectrum for the three pavement surfaces. To construct this spectrum the two longitudinally tined and the two transversely tined sections were averaged. These plots show that the transverse tined sections contain both low frequency noise (rumble – at approximately 700 Hz) and high frequency noise (a whine at about 1400 Hz). Either tinning or grooving in the longitudinal direction appears to mitigate the high frequency noise and longitudinal grooved appears to reduce the low frequency noise (rumbling).

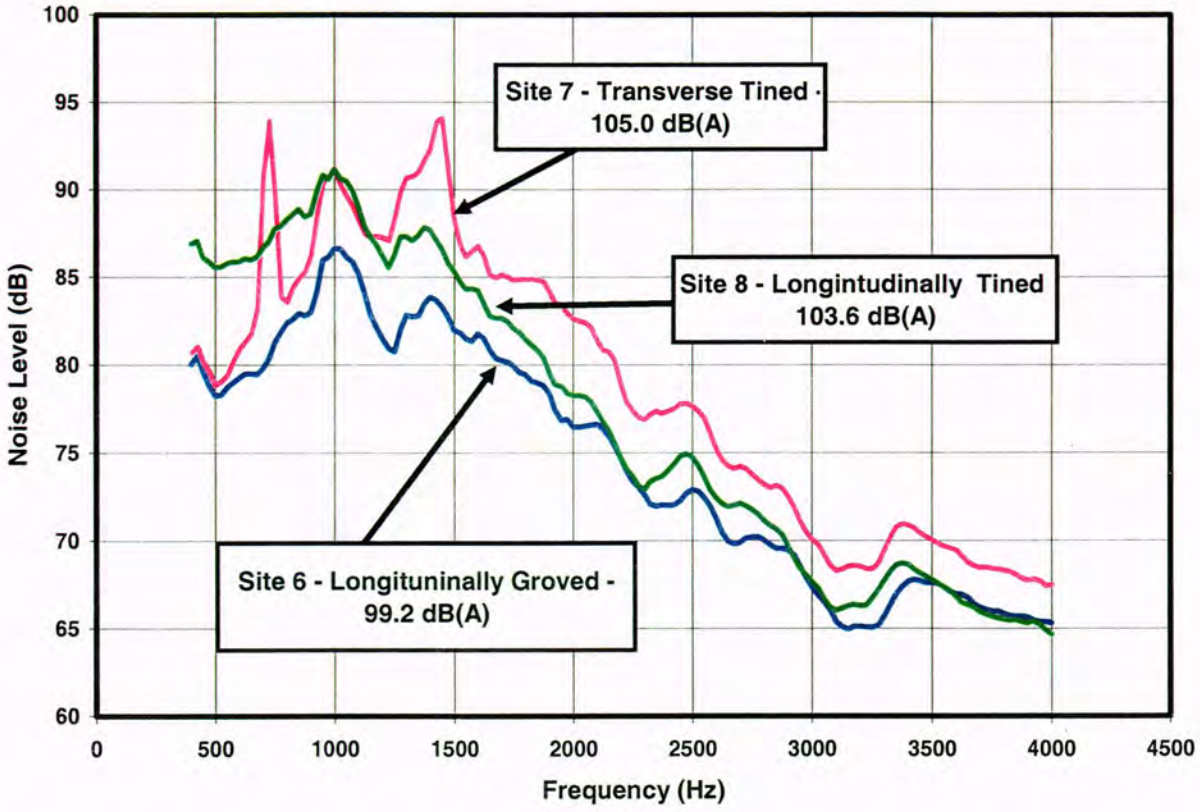


Figure 13 – Frequency Spectrum for PCCP Pavements

Variability of Pavement Noise

To adequately predict the noise level at a point along a roadway (e.g. a person's backyard or a swimming pool by a hotel), it is not only necessary to have an understanding of the total magnitude of noise that emits from traffic on a paved surface but also the variability of the noise along the pavement surface. The standard data collection process used for this study was to determine the average noise level over approximately one mile of paved surface. The noise level longitudinally down the pavement surface will vary due to surface variability. The test sections for this study were approximately one mile long and the testing was done at 60 miles per hour; therefore, each section represents approximately 60 seconds of data. Each test section was broken into two second segments (or sections of 176 feet). Each of these two second segments was analyzed to determine the noise level in dB(A) for that two second section. Table 5 shows the results of that analysis. The HMA pavement had an average range of 2.7 dB(A). The PCCP sections had an average range of 4.6 dB(A).

Table 5 – Longitudinal Variability of Noise Data

Site No.	Route & Direction	Lane No. Tested	Mix Type of Surface	Average Both Tire Types dB(A)	Range dB(A)	Standard Deviation dB(A)
1	IR 15 S	3	OGFC	93.7	2.6	0.74
2	US 95 N	1	OGFC	93.7	2.8	0.60
3	US 95 N	1	OGFC	93.8	2.5	0.74
4	SR 160 W	1	OGFC	98.8	2.9	0.73
5	IR 215 Interim Frontage Road W	1	Plant mix Bituminous Surface	98.0	2.5	0.80
6	IR 15 N	3	PCCP – Longitudinal Grooving	99.2	4.2	0.86
7	I 15 S	3	PCCP – Transverse Tined	105.0	5.2	1.23
8	IR 15 S	1	PCCP – Longitudinal Tined	103.6	6.3	1.34
9	IR 215 E	3	PCCP – Transverse Tined	102.2	3.5	0.83
10	IR 215 E	3	PCCP – Longitudinal Tined	100.8	4.0	1.06

SUMMARY

In today's society, traffic noise is a serious problem. The term "noise" should not be confused with the term sound. Noise is the generation of sounds that are unwanted. With respect to traffic, noise would be the generation of sounds that affect the quality of life for persons near roadways. Therefore, traffic noise can be considered an environmental pollution because it lowers the standard of living. Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will reduce the level of noise generated on roadways.

This paper provides the results of testing to define the noise levels of selected highway sections in the vicinity of Las Vegas, NV. Ten pavement surfaces were tested to determine their tire/pavement noise levels. The average noise levels ranged from 105.0 dB(A) to 93.7 dB(A) at the tire/pavement interface.

Four OGFC wearing surfaces were tested. The average noise level was 95.0 dB(A) with a range of 93.7 dB(A) to 98.8 dB(A). The one HMA surface tested had a noise level of 98.0 dB(A).

The noise levels for the PCCP pavements ranged from 99.2 dB(A) to 105.0 dB(A). The quietest surface was a longitudinally grooved PCCP. The average noise level for the five PCCP surfaces tested was 102.2 dB(A).

CONCLUSIONS & RECOMMENDATIONS

Based on the results of the testing conducted for the Nevada DOT it is concluded that:

1. The OGFC pavements will provide a significantly quieter pavement surface than the PCCP pavements.
2. It is recommended that if the Nevada DOT plans to construct a PCCP pavement that it be longitudinally grooved or diamond ground. These texturing systems appear to provide the quietest PCCP pavement surface.
3. It is recommended that the Nevada DOT consider the possibility of building a test section where the thickness of the OGFC is varied to determine the effect of thickness on noise level.

REFERENCES

(1) Highway Traffic Noise in the United States – Problem and Response, Federal Highway Administration, US Department of Transportation, April 2000

(2) Sandberg, Ulf and Jerzy A. Easement, Tyre/Road Noise Reference Book, Informex, 2002

(3) Highway Noise Fundamentals, Noise Fundamentals Training Document., Federal Highway Administration, US Department of Transportation, September 1980

(4) "Sound Barriers & Noise Control", Arizona Milepost, Vol. 3, No. 2, Spring 2002

(5) International Organization for Standardization, Measurement of the Influence of Road Surfaces on Traffic Noise- Part 1, Statistical Pass-by Method 11819-1., 1997

(6) Lee, Cynthia S.Y., and Gregg G. Fleming, Measurement of Highway-Related Noise, FHWA-PD-96-046, May 1996

(7) International Organization for Standardization, Measurement of the Influence of Road Surfaces on Traffic Noise- Part 2, Close-Proximity Method ISO Standard 11819-2., 1997

(8) Kuemmel, D. A., R. C. Sonntag, James Crovetti, Y. Becker, "Noise and Texture on PCC Pavements – Results of a Multi-state Study" Wisconsin Report SPR 08-99, June 2000

APPENDIX A

Tires Used for Testing

TIRES USED FOR STUDY

Figure A – 1 Goodyear Aquatred

Figure A -2 Uniroyal TigerPaw

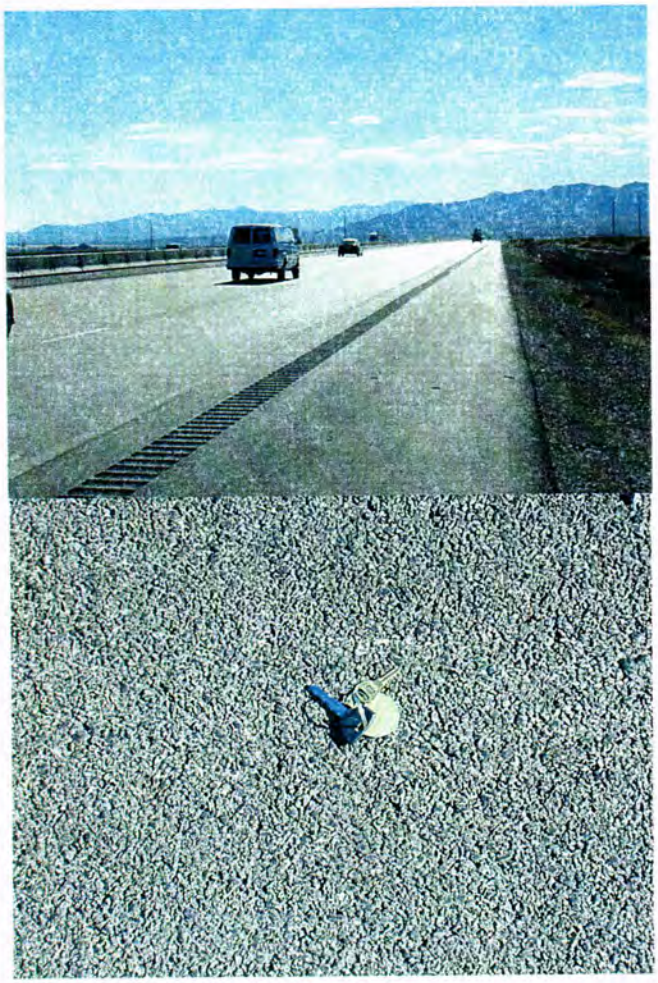
APPENDIX B

Photos and Frequency Spectrum

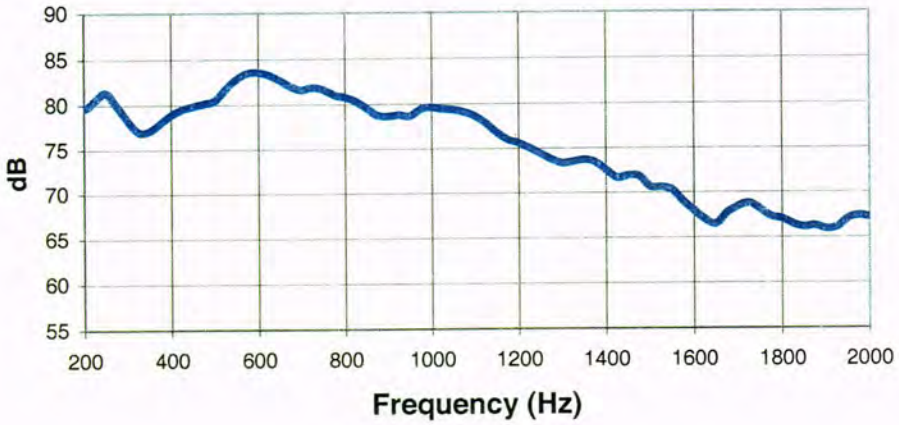
For

Each of the Pavement Sections Tested

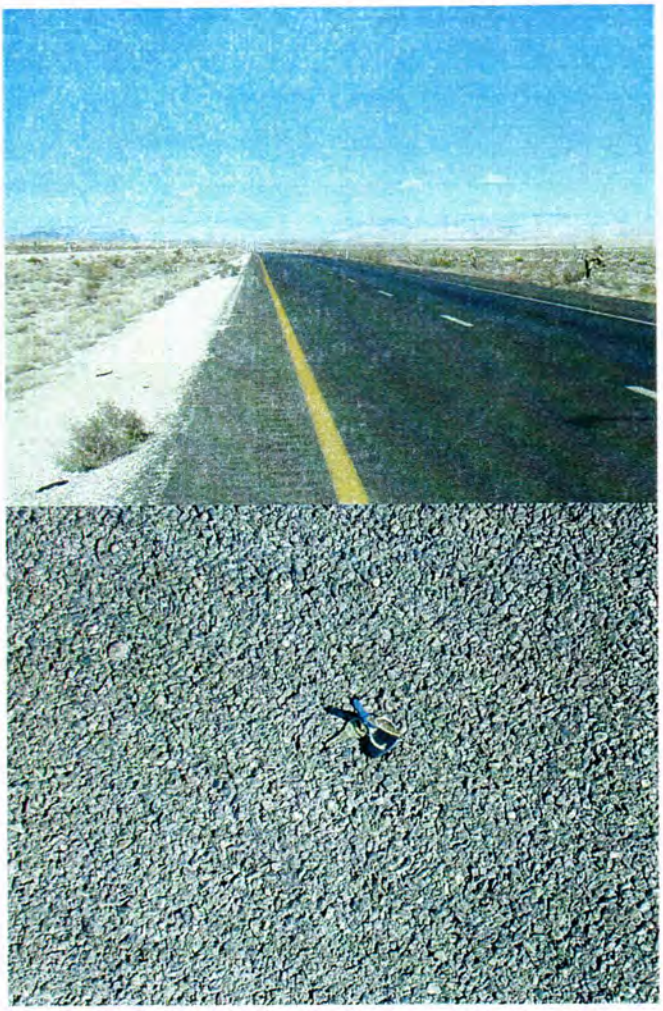
Nevada Site 1 – I –15 S OGFC {93.8 dB(A)}



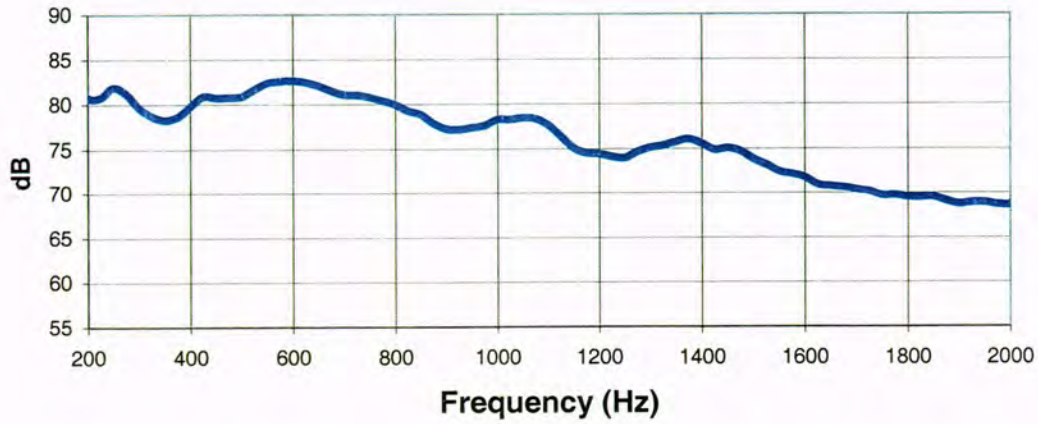
NV 1 I-15 S Milepost 12.0 to 11.0 OGFC



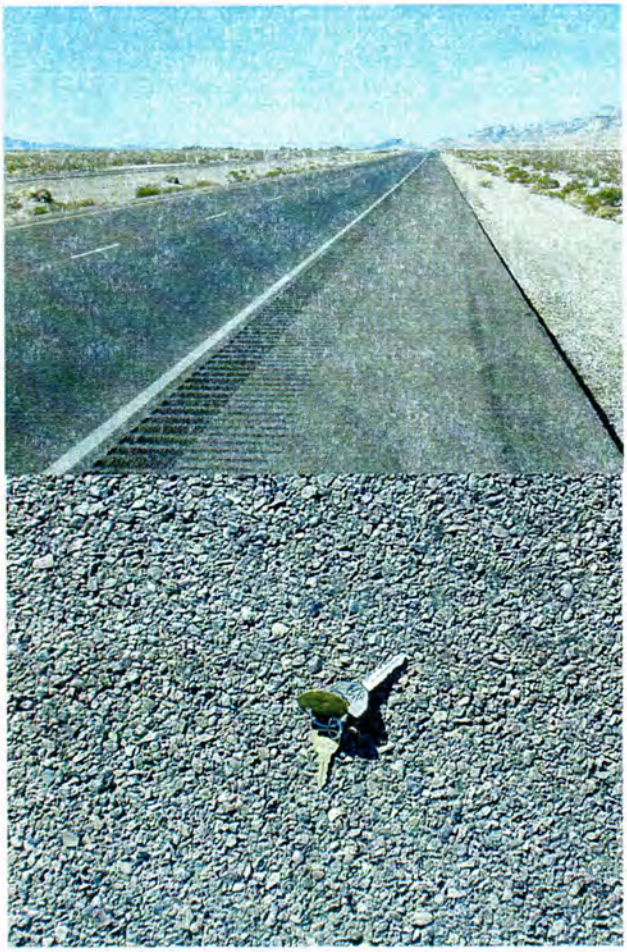
Nevada Site 2 – US 95 N OGFC {93.6 dB(A)}



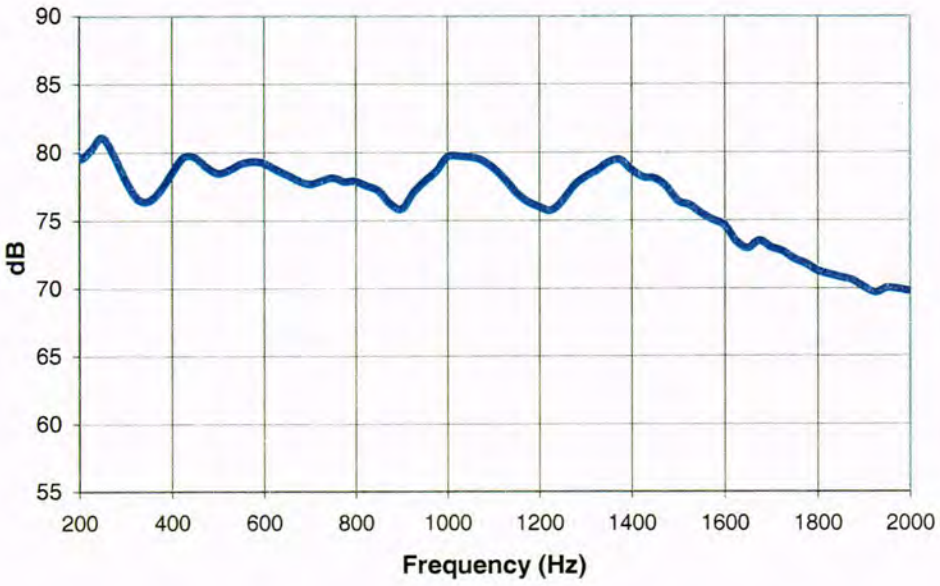
NV 2 US 95 N Milepost 108.0 to 109.0 OGFC Aqua



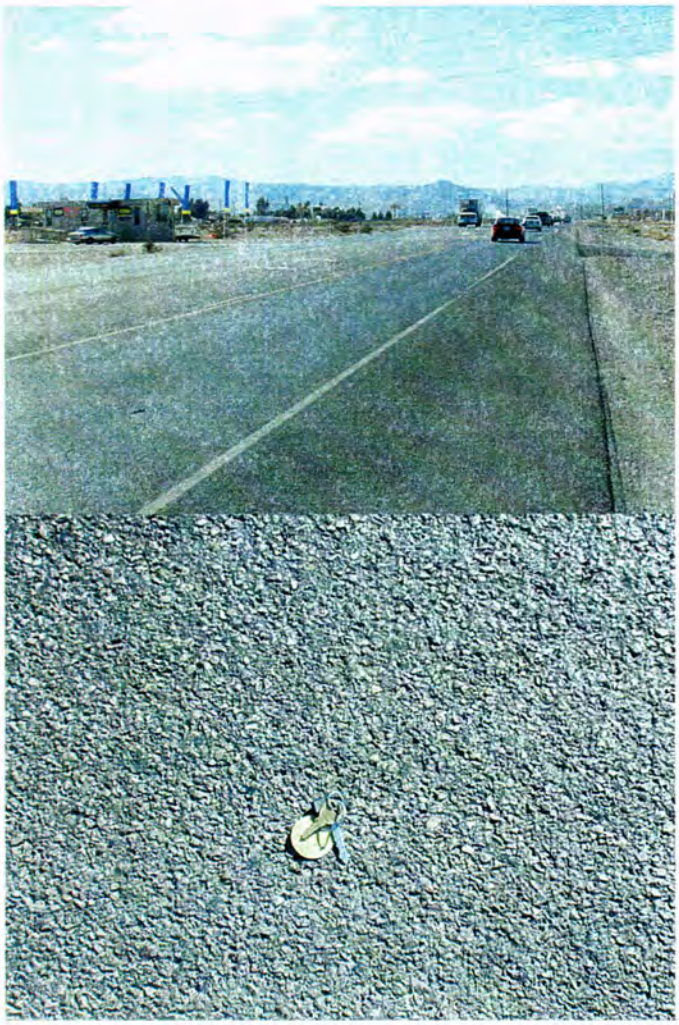
Nevada Site 3 – US 95 N OGFC {93.8 dB(A)}



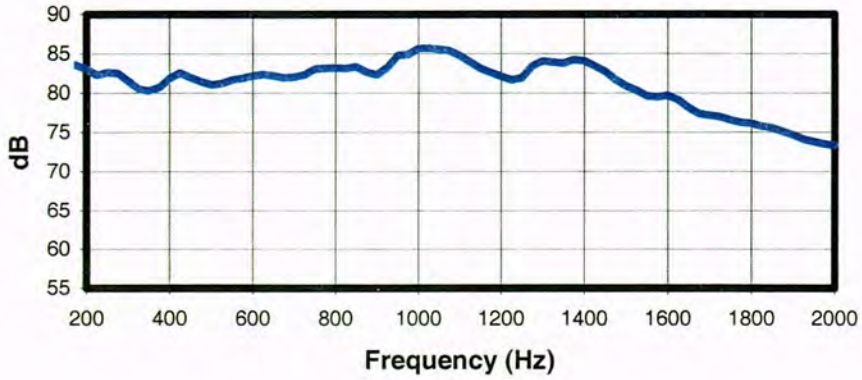
NV 3 US 95N Milepost 119.9 to 120.8



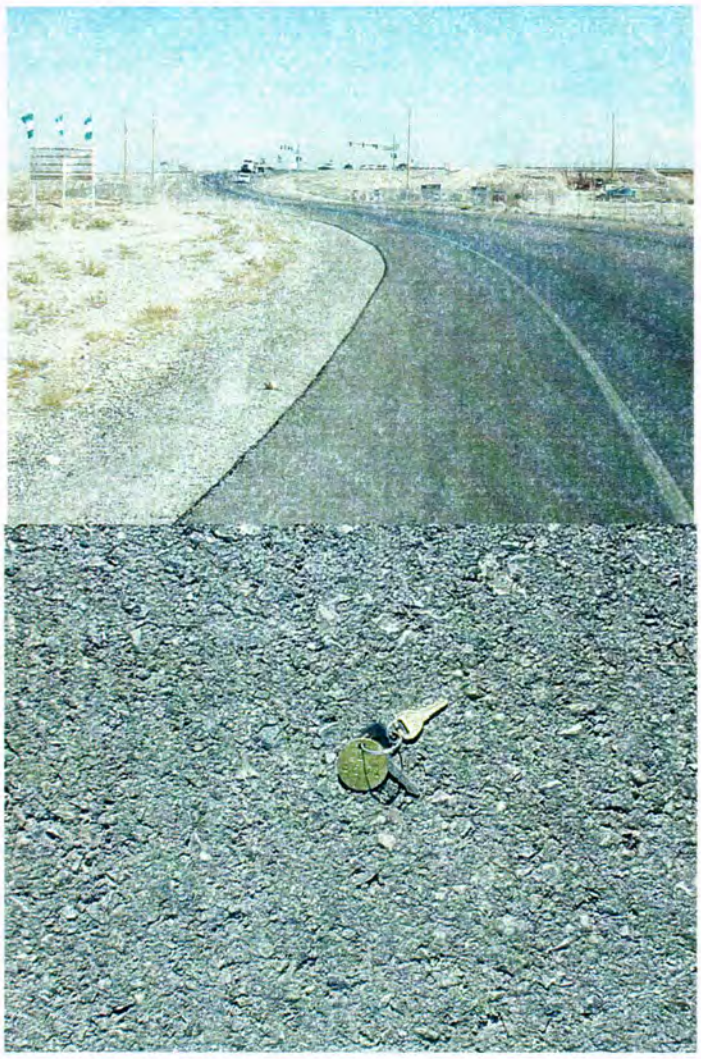
Nevada Site 4 – SR 160 W OGFC {98.8 dB(A)}



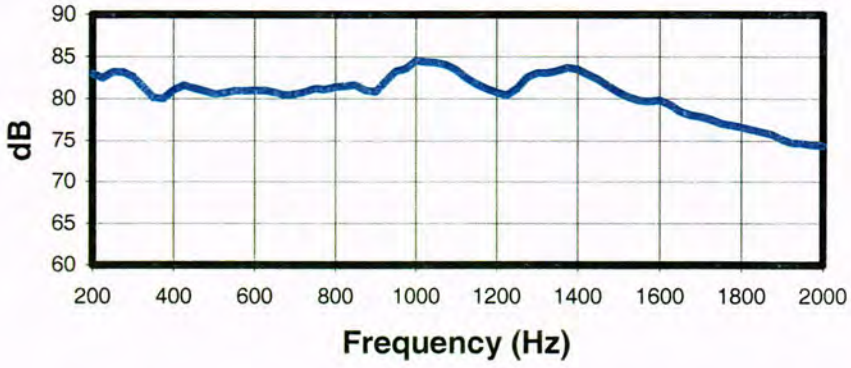
NV 4 - SR 160 W Milepost 2.3 to 3.3 (OGFC)



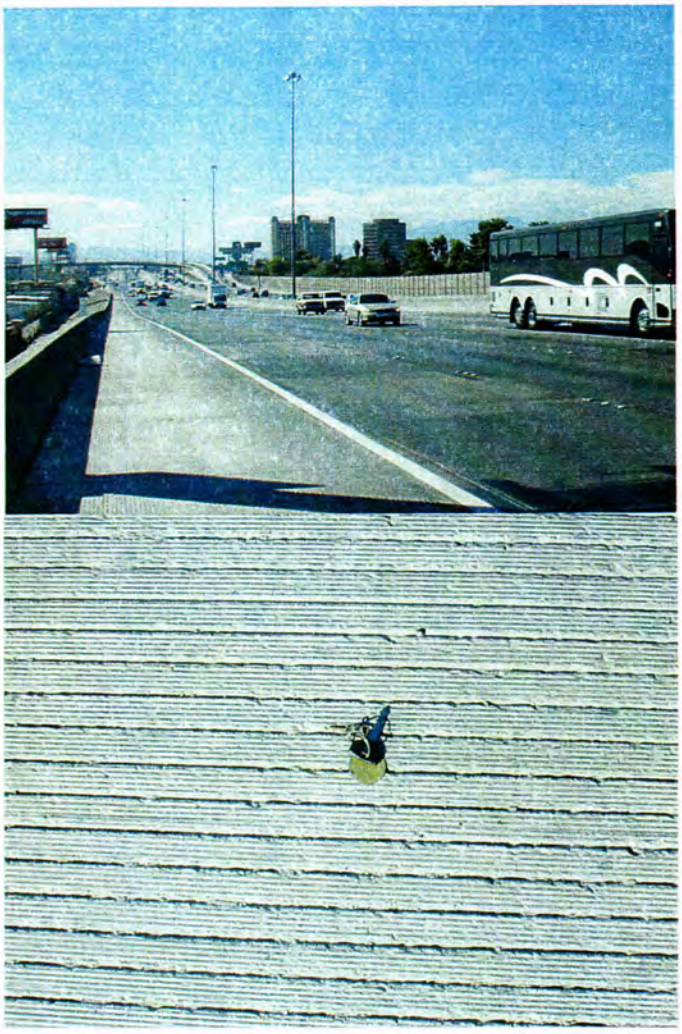
Nevada Site 5 – I 215 W – PBS – {98.1 dB(A)}



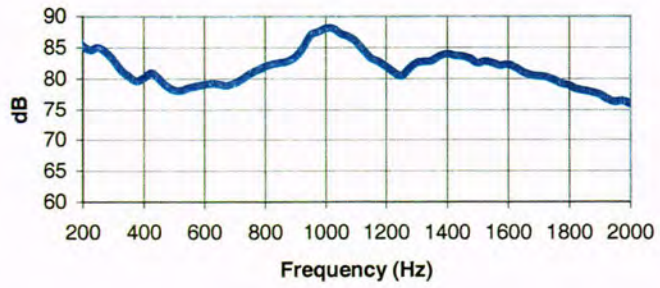
NV 5 CR 215 W (Jones to Rainbow) PBS



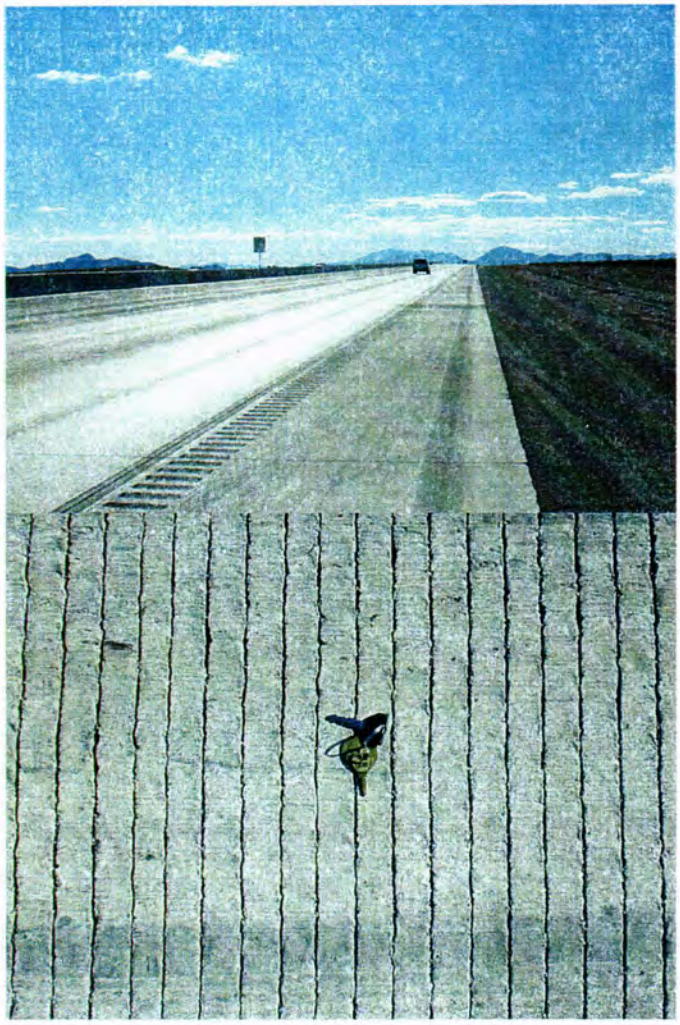
Nevada Site 6 I 15 N – PCCP --- Longitudinal Grooved – {99.2 dB(A)}



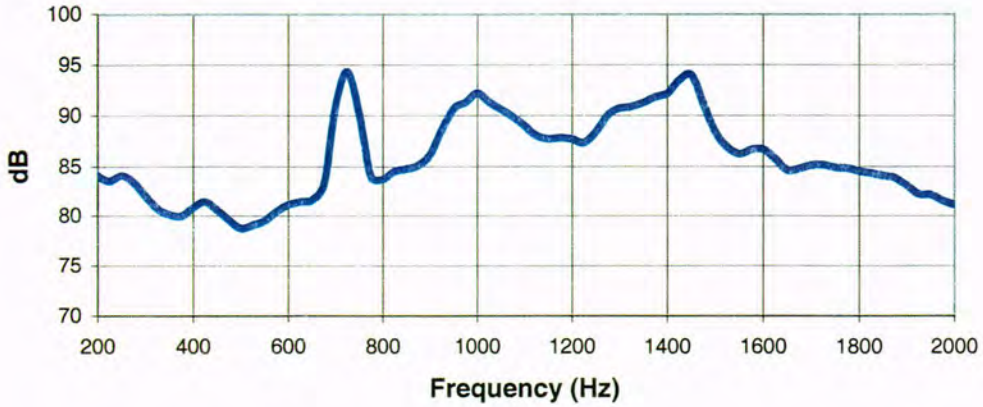
NV 6 I-15 N Milepost 40.5 to 41.5
LonGroove PCCP



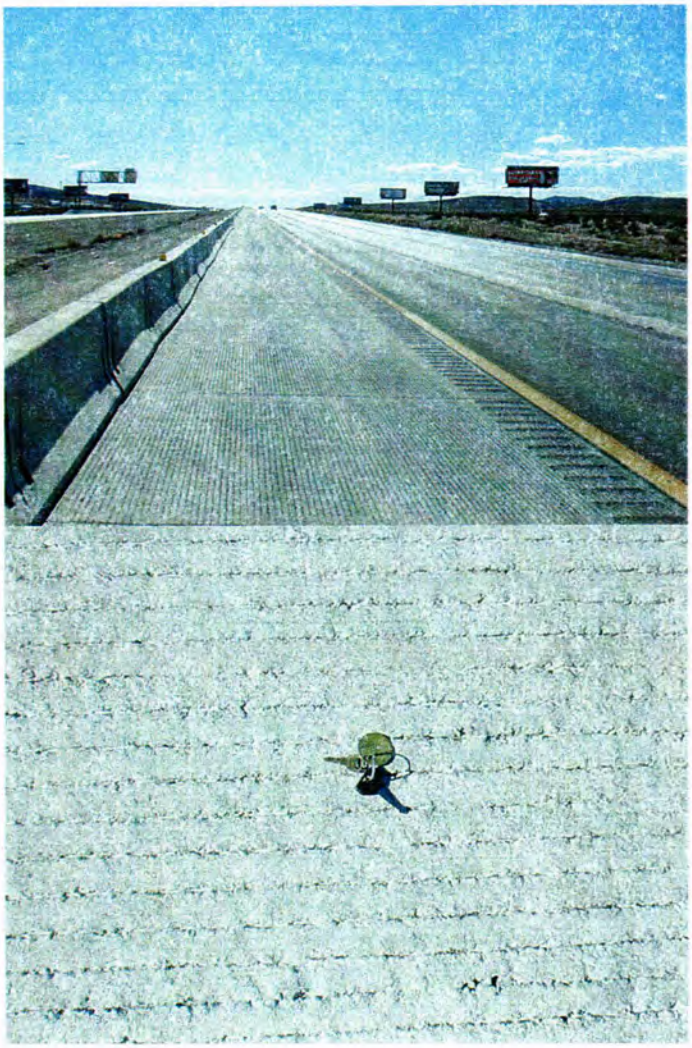
Nevada Site 7 – IR–15 PCCP – Transverse Tined – {105.1 dB(A)}



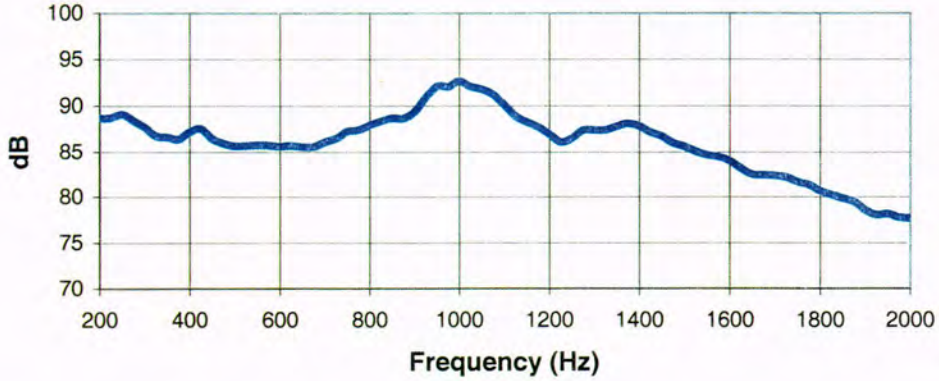
NV 7 I-15S Milepost 21.5 to 20.5 Transverse Tined PCCP



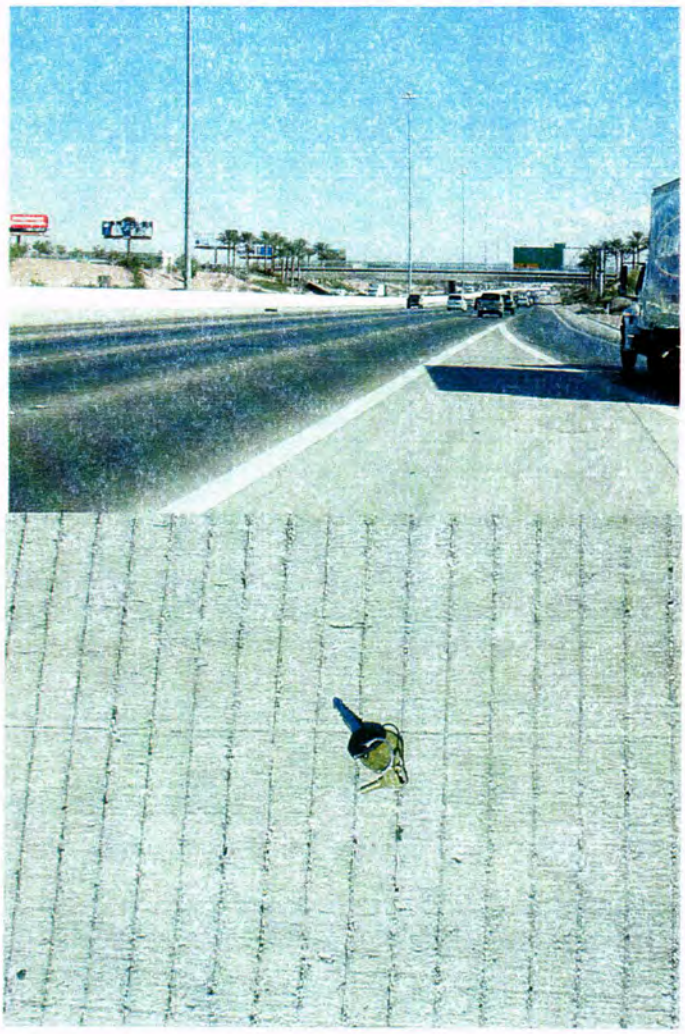
Nevada Site 8 – IR 15S – PCCP - Longitudinal Tined {104.2 dB(A)}



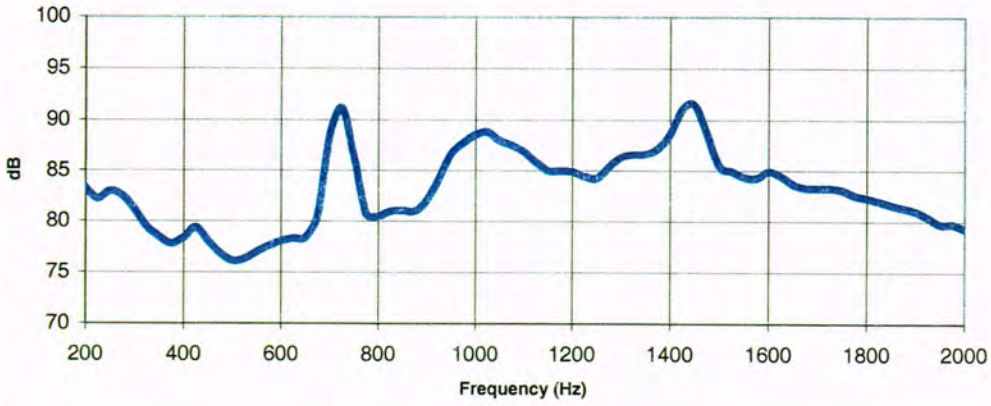
NV 8 I-15S Milepost 25.0 to 24.0 Long Tined PCCP



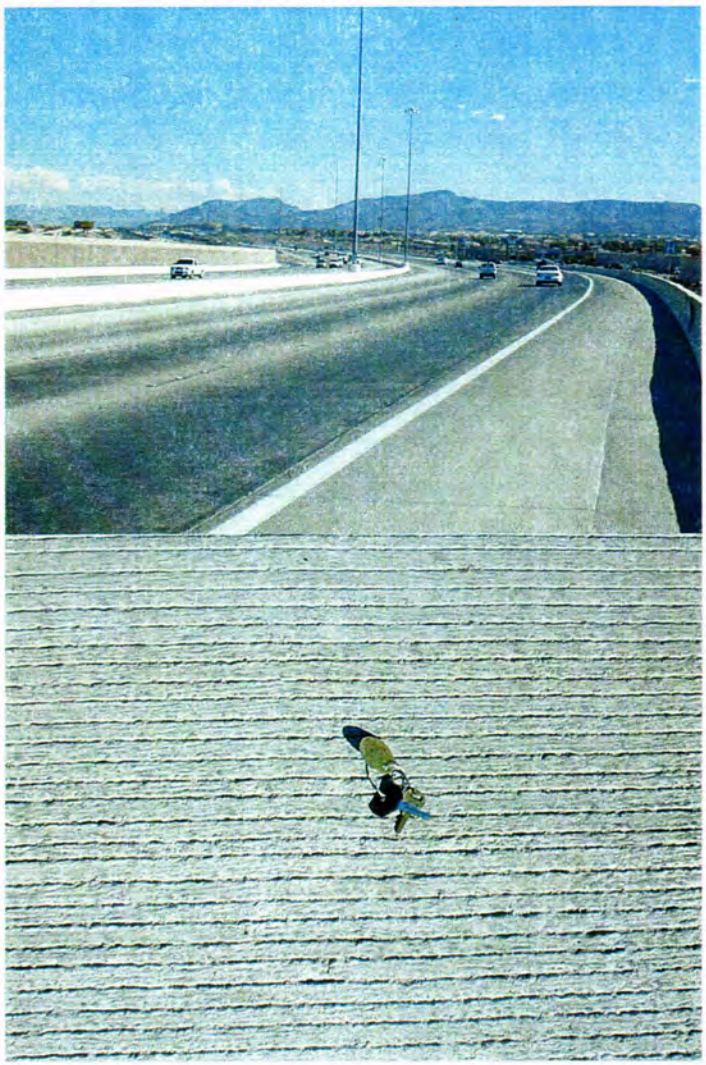
Nevada Site 9 – IR – 215 E PCCP – Transverse Tined {102.2 dB(A)}



NV 9 I-215 E Milepost 10.0 to 9.0 Trans Tined PCCP



Nevada 10 – IR 215 E – PCCP Longitudinal Tined {101.4 dB(A)}



NV 10 I-215E Milepost 6.0 to 5.0 Long Tined PCCP