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Final Report**

2005 COLORADO DOT TIRE/PAVEMENT NOISE STUDY

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November 2006

**COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH**

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16. Abstract In the fall of 2003, NCAT conducted a study to determine the tire/pavement noise characteristics of 13 Hot Mix Asphalt (HMA) and 6 Portland Cement Concrete Pavements (PCCP) in Colorado. In the fall of 2004, NCAT was asked to conduct another tire/pavement noise study for the Colorado DOT. Fifteen HMA and six PCCP surfaces were tested. In addition a short PCC pavement test section built to evaluate various textures was evaluated. In 2005 NCAT was asked to test the same sites that were tested in 2004. This paper provides the results of the 2003, 2004, and 2005 testing. This testing was done by NCAT using a close proximity noise trailer that was built in accordance with the requirements of ISO Standard 11819-2. It was found in this study that the noise levels of both the HMA and the PCCP pavements in Colorado do increase with age, but at a very slow rate and that the rate of increase varies with the pavement type tested. Implementation: It is recommended that the Colorado DOT continue this type of study over an extended period of time to obtain an accurate measure of the effect of pavement age on noise level.			
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COLORADO DOT TIRE/PAVEMENT NOISE STUDY

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EXECUTIVE SUMMARY

In 2003 the National Center for Asphalt Technology conducted a study of the noise characteristics of 29 pavement surfaces: 14 Hot Mix Asphalt (HMA) and 15 Portland Cement Concrete (PCC). This study provided the Colorado DOT with a base line on what effect the choice of the surface type will have on the tire/pavement noise generated by the Colorado traffic. In 2004 the Colorado DOT requested that NCAT test 13 HMA and 14 PCC sites. Thirteen of the sites tested in 2003 were tested again in 2004 to start the development of a database on the effect of traffic and time on tire/pavement noise. In 2005 NCAT was asked to test these surfaces for a third time to continue the development of an understanding of the effect of time and environment on the noise level of both PCC and HMA pavements. In the 2005 study, 25 sites that were tested in 2004 were retested. This paper provides the results of the 2005 testing. This testing was done by NCAT using a close proximity noise trailer that was built in accordance with the requirements of ISO Standard 11819-2.

It was found in this study that the noise levels of both the HMA and the PCC pavements in Colorado do increase with age, but at a very slow rate and that the rate of increase varies with the pavement type tested.

Implementation Statement

It is recommended that the Colorado DOT continue the process of evaluating the effect of pavement age on tire-pavement noise. It is the author's understanding that the Colorado DOT has awarded a contract to continue these types of tests.

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INTRODUCTION

In 2003 the National Center for Asphalt Technology conducted a study of the noise characteristics of 29 pavement surfaces: 14 Hot Mix Asphalt (HMA) and 15 Portland Cement Concrete (PCC). This study provided the Colorado DOT with a base line on what effect the choice of the surface type will have on the tire/pavement noise generated by the Colorado traffic. In 2004 the Colorado DOT requested that NCAT test 13 HMA and 14 PCC sites. Thirteen of the sites tested in 2003 were tested again in 2004 to start the development of a database on the effect of traffic and time on tire/pavement noise. In 2005 NCAT was asked to test these surfaces for a third time to continue the development of an understanding of the effect of time and environment on the noise level of both PCC and HMA pavements. In the 2005 study 25 sites that were tested in 2004 were retested. This paper provides the results of the 2005 testing.

BACKGROUND

Research in Europe and in the US has indicated that it is possible to build pavement surfaces that will provide low noise roadways. The National Center for Asphalt Technology (NCAT), the American Concrete Pavement Association (ACPA) and the Federal Highway Administration (FHWA) have been conducting research to develop a pavement selection guide or design manual for use by the State Departments of Transportation and others to design low noise 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.

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 (1):

1. A surface with a smooth 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.

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 Open Grade Friction Course (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) and are provided in this report for use in comparing test data reported for Colorado's pavements with the data from other states:

1. HMA Pavements
 - a. Open-graded (fine gradation) Mixes - 93 bB(A).
 - b. Dense graded HMA - 97 dB(A).
 - c. Stone Matrix Asphalt Mixes - 96 dB(A).
 - d. Open-graded (coarse gradation) Mixes - 97 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)

TEST PROCEDURE

The CPX method consists of measuring the sound levels near the tire/pavement interface for a tire enclosed in a trailer or specially modified vehicle. The use of the CPX method testing is widespread in Europe. The requirements for the CPX trailer are described in ISO Standard 11819-2 (2). 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. The trailer was built following the requirements of the ISO Standard. A picture of the NCAT trailer is shown in Figure 1.



Figure 1. NCAT Close Proximity Trailer

The ISO Standard calls for the measurement of sound pressure. The microphones are mounted 200 mm from the center of the tire and 100 mm above the surface of the pavement (see Figure 2). 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.

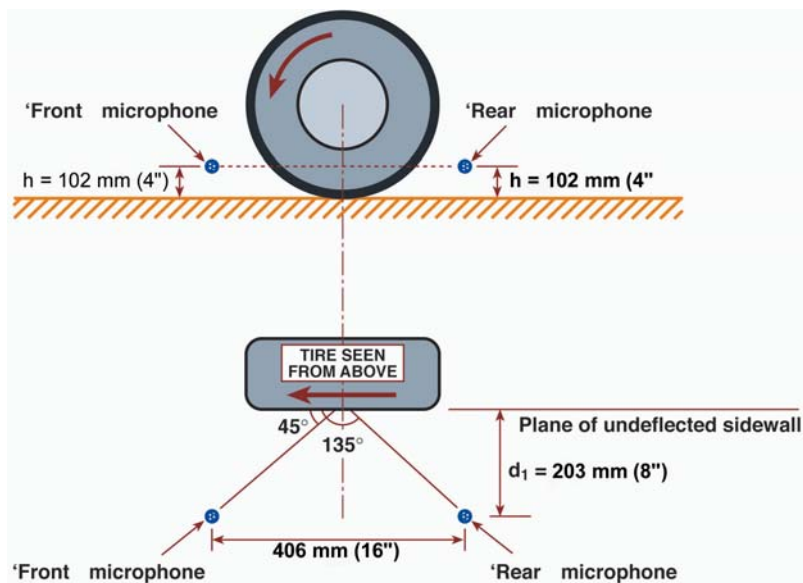


Figure 2. Diagram Showing Microphone Locations on NCAT CPX Trailer

Research by NCAT, the Arizona DOT, and California DOT has shown that the difference between the close-proximity testing and the noise level at 25 feet from the edge of the roadway is approximately 23 bB(A).

TEST RESULTS

In October 2005 the National Center for Asphalt Technology tested eighteen pavement surfaces (12 HMA and 6 PCCP) located throughout Colorado. In addition NCAT tested a PCC pavement section on I-70 east of Denver (this section is a section constructed by CDOT to evaluate different surface textures). The Colorado DOT chose the pavements to be tested. All testing was done at 60 mph using two tires. Three tests were conducted with each tire on each pavement surface. The reason for conducting the tests with two tires is to provide a better representation of the tire/pavement noise levels for each surface type. The two tires used were a Goodyear Aquatread and a Uniroyal Tiger Paw. Appendix A contains pictures of the tire tread pattern. Prior to and at the completion of testing each day the microphones and measurement system are calibrated by inducing a known noise (both dB and frequency) into the microphones to insure that the microphones are properly measuring the noise level.

Table 1 contains a listing of the test sites and Table 2 contains a summary of the test results. Appendix B contains pictures of each of the surfaces tested in this study.

Table 1. Listing of Sites

Site No.	Surface Texture	Location	Milepost		Age	AADT	ESAL/yr.	Traffic Level	Elevation	Climate
			Start	End						
18	DROP	I-70 Genesee	253	252	2003	65,000	485,000	High	7,670	Severe
2	SMA (3/4)	US83/Hilltop	57	58	2004	42,000	182,000	Medium	5,870	Moderate
19		*I-70/Chief Hosa	252	251	2003	54,000	457,000	High	7,670	Severe
3		I-70/Pecos	272	271	2003	115,000	621,000	High High	5,280	Moderate
14	SMA (1/2)	*US50/Kannah Cr	48	47	2002	5,000	108,000	Low to Medium	4,970	Mild
6	SMA (3/8)	Hwy74/Evergreen			2004	21,000	97,000	Medium	7,040	High
15	SX (1/2)	US50/Kannah Cr	47	48	2002	5,000	108,000	Low to Medium	4,970	Mild
8		US85/Sedalia	189	188	2003	20,000	182,000	Medium to High	5,860	Moderate
10		I-70/Bakerville	222	221	2001	27,000	318,000	Medium to High	9,200	Severe
11	S (3/4)	C470/Morrison	5	6	2003	69,000	443,000	Medium to High	5,800	Moderate
12		US287/Laporte	262	261	2003	9,000	245,000	Medium to High	5,060	Moderate to Severe
16	NovaChip	*US82/Snowmass			2002	16,000	85,000	Medium	5,950	Severe
1		* SH58/Golden	2	3	2003	14,000	135,000	Low to Medium	5,680	Moderate
7	PCCP (Longitudinal Tining)	*I-25 N. Hwy 7	231	230	2003	66,000	1,330,000	High	5,020	Moderate
4		*US285/Turkey Ck	243	242	2001	23,000	179,000	Medium to High	7,100	Moderate to Severe
13	PCCP (Grooving)	I-25/Colo Springs	143	144	2002	96,000	1,515,000	High High	6,010	Moderate
17	PCCP (Carpet Drag)	SH121 S. Jeffco	2	0.5	2002	46,000	104,000	High	5,360	Moderate
20		I-70/Rifle	91.75	+500 ft.	1976	14,000	595,000	Medium	5,350	Moderate
5	PCCP (Grinding)	*US285/Tiny Town	245	244	2001	29,000	219,000	High	6,480	Moderate to Severe
21	SMA	I-70W Gypsum to Eagle	142	141	1996	20,000	369,000	Medium	6,470	Moderate to Severe
22	PCCP (Grinding)	I-70/Rifle	91	92	2005	14,000	595,000	Medium	5,360	Moderate

Table 2. Summary of Test Results

Site No.	Surface Texture	Location	Age	AADT	ESAL/yr	Average Noise Level (dB(A))		
						2005	2004	2003
18	OGFC	I-70/Genesse	2003	65,000	485,000	-	97.1	95.2
2	SMA (3/4)	US83/Hilltop	2004	42,000	182,000	99.6	96.4	-
19		I-70/Chief Hosa	2003	54,000	457,000	99.7	99.2	96.3
3		I-70/Pecos	2003	115,000	621,000	97.4	99.5	-
14	SMA (1/2)	US50/Kannah Cr	2002	5,000	108,000	97.7	98.3	96.2
6	SMA (3/8)	Hwy74/Evergreen	2004	21,000	97,000	98.2	94.6	-
15	SX (1/2)	US50/Kannah Cr	2002	5,000	108,000	98.3	98.7	-
8		US85/Sedalia	2003	20,000	182,000	96.4	96.2	95.6
10		I-70/Bakerville	2001	27,000	318,000	101.1	97.1	-
11	S (3/4)	C470/Morrison	2003	69,000	443,000	98.2	101.1	-
12		US287/Laporte	2003	9,000	245,000	99.9	97.2	-
16	NovaChip	US82/Snowmass	2002	16,000	85,000	99.9	101.1	98.9
1		SH58/Golden	2003	14,000	135,000	101.1	98.4	95.1
7	PCCP (Longitudinal Tining)	I-25 N. Hwy 7	2003	66,000	1,330,000	99.9	98.3	97.5
4		US285/Turkey Ck	2001	23,000	179,000	101.1	99.9	98.6
13	PCCP (Grooving)	I-25/Colo Springs	2002	96,000	1,515,000	98.2	98.5	-
17	PCCP (Carpet Drag)	SH121 S. Jeffco	2002	46,000	104,000	99.4	99.7	-
20		I-70/Rifle	1976	14,000	595,000	97.5	104.0	-
5	PCCP (Grinding)	US285/Tiny Town	2001	29,000	219,000	100.9	100.9	98.0
22		I-70 Rifle	2005	14,000	595,000	98.5	-	-
21	SMA	I-70W Gypsum to Eagle	1996	20,000	369,000	98.5	100.4	-

Discussion of HMA Test Results

Table 3 presents the results of the noise testing on the HMA surfaces. The data shows that in general the coarser the gradation the higher the noise level as measured by the CPX trailer. The average noise level increased about 0.7 dB(A) for all of the HMA surfaces from 2004 to 2005. On four of the sites the measured noise level decreased from 2004 to 2005. Without texture measures and/or air void data on the sites the reason for this cannot be determined. This type of testing was beyond the scope of this project. It should be included in any future projects to evaluate noise level changes conducted by the Colorado DOT.

Table 3. Summary of HMA Test Results with NCAT CPX Noise Trailer

Type Mix	Site	Year Constructed	Noise Level dB(A)		
			2005	2004	2003
SMA (3/4)	2	2004	99.6	96.9	-
	3	2003	97.4	99.5	-
	19	2003	99.7	99.2	96.3
	Average		98.9	98.5	-
SMA (1/2)	14	2002	97.7	98.3	96.2
SMA (3/8)	6	2004	98.2	94.6	-
Superpave SX (1/2)	8	2003	96.4	96.2	95.6
	10	2001	101.1	97.1	-
	15	2002	98.3	98.7	-
	Average		98.6	97.3	-
Superpave S (3/4)	11	2003	98.2	101.1	-
	12	2003	99.9	98.4	-
	Average		99.0	99.7	-
NovaChip	1	2003	101.1	98.4	95.1
	16	2002	99.9	101.1	98.9
	Average		100.5	99.6	97.0
OGFC	18	2003	-	97.1	95.2
Average for All Surfaces			98.9	98.2	96.2

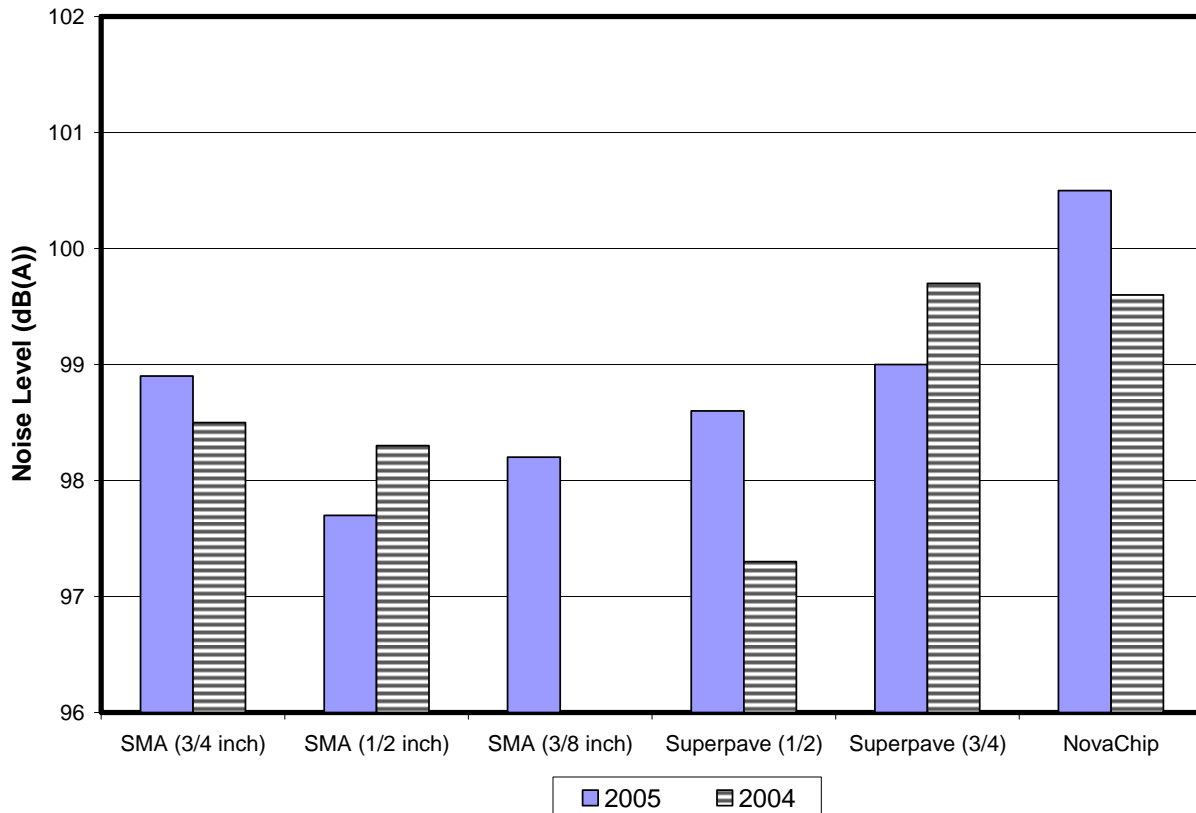


Figure 3. Comparison of HMA Test Data for 2004 and 2005

Discussion of PCCP Test Result

Seven different PCC pavement sections were tested throughout Colorado. The results are presented in Table 4. In addition, nine experimental sections on I-70 east of Denver were evaluated. The I-70 sections were built by the Colorado DOT to evaluate various texturing procedures for possible use by the Colorado DOT. The data for the I-70 sections is shown in Table 5. The test data indicates that the average noise level increased 0.2 dB(A) (shown in table 4) from 2004 to 2005 and decreased 1.1 dB(A) on the I-70 sections (shown in table 5). This would indicate that the average noise level for the PCCP pavements in Colorado did not change from 2004 to 2005. On both of the longitudinally tined sections the noise level increased at a rate of about 1 dB(A) per year from 2003 to 2005.

Table 4. Summary of PCCP Test Results

Surface Type	Site	Yr Const.	Noise Level (dB(A))		
			2005	2004	2003
Longitudinally Tined	4	2001	101.1	99.7	98.7
	7	2002	99.9	98.3	97.5
	Average		100.5	99.0	98.1
Grooved	13	2002	98.2	98.5	-
Ground	5	2002	100.7	100.9	98.0
	22	2005	98.5	-	-
	Average		99.6	100.9	98.0
Carpet Drag	17	2002	99.4	99.7	-
	20*	1976	-	104.0	-
	Average		98.5	101.9	-
			99.6	99.4	

*This site was diamond ground in 2005 and is not included in the averages.

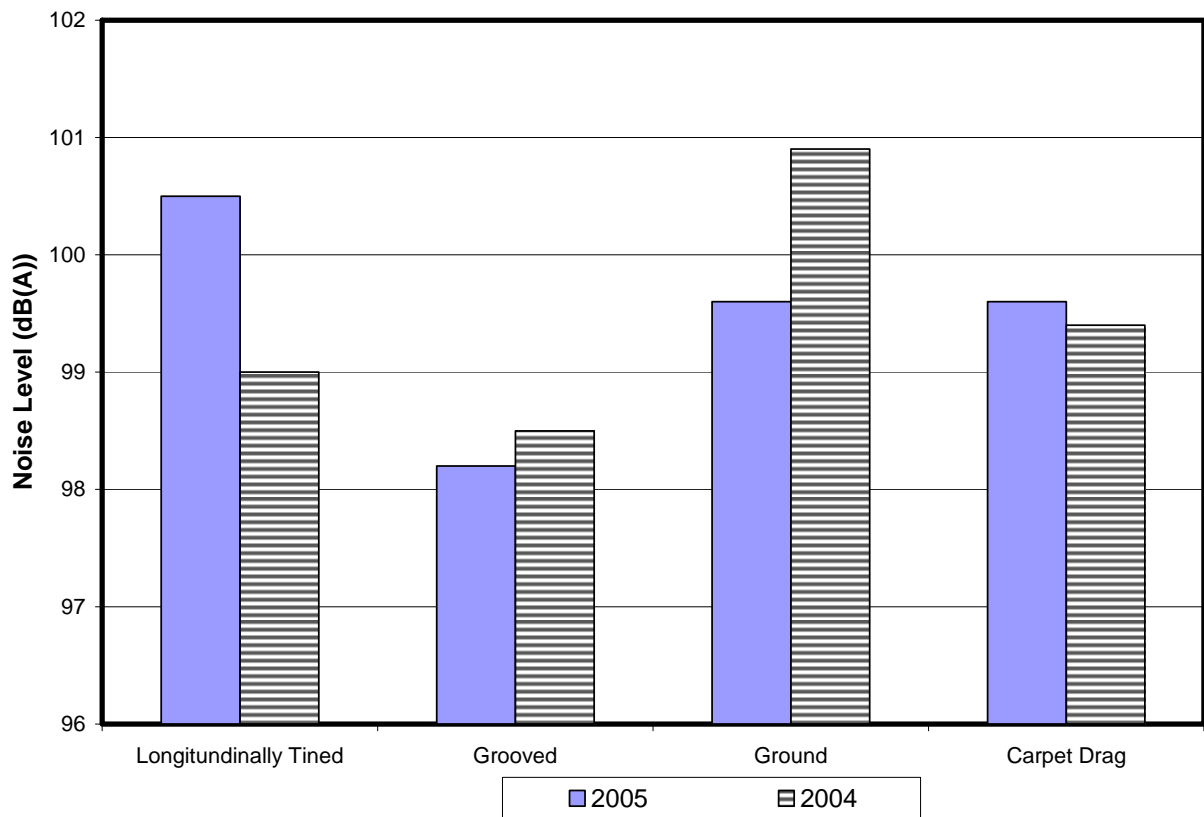


Figure 4. Comparison of PCCP Test Data for 2004 and 2005

Table 5. Summary of Results on I-70 PCCP Texture Test Sections

Section	Length	Type of Texture	Noise Level dB(A)	
			2005	2004
1 MP 335.3	2800	Transverse 1" Tining	106.6	106.6
2	2500	Transverse Astro-turf No Tining	98.4	99.9
3	2100	Longitudinal Astro/Turf Transverse Random Tining	105.5	107.0
4	1700	Longitudinal Astro/Turf Transverse 1/2 " Tining	102.2	104.2
5	1000	Longitudinal Astro-Turf/Transverse Random Tining	104.5	104.6
6	2800	Longitudinal Astro-Turf/Transverse 1" Tining	105.9	105.8
7	1000	Longitudinal Astro-Turf /Longitudinal Sawing 3/4"	97.8	99.8
8	1000	Longitudinal Astro-Turf/ No Tining	97.5	98.9
9 MP 338.3	1000	Longitudinal Astro-Turf /Longitudinal 3/4 " Tining	97.8	99.8
Average of all surfaces			101.8	102.9

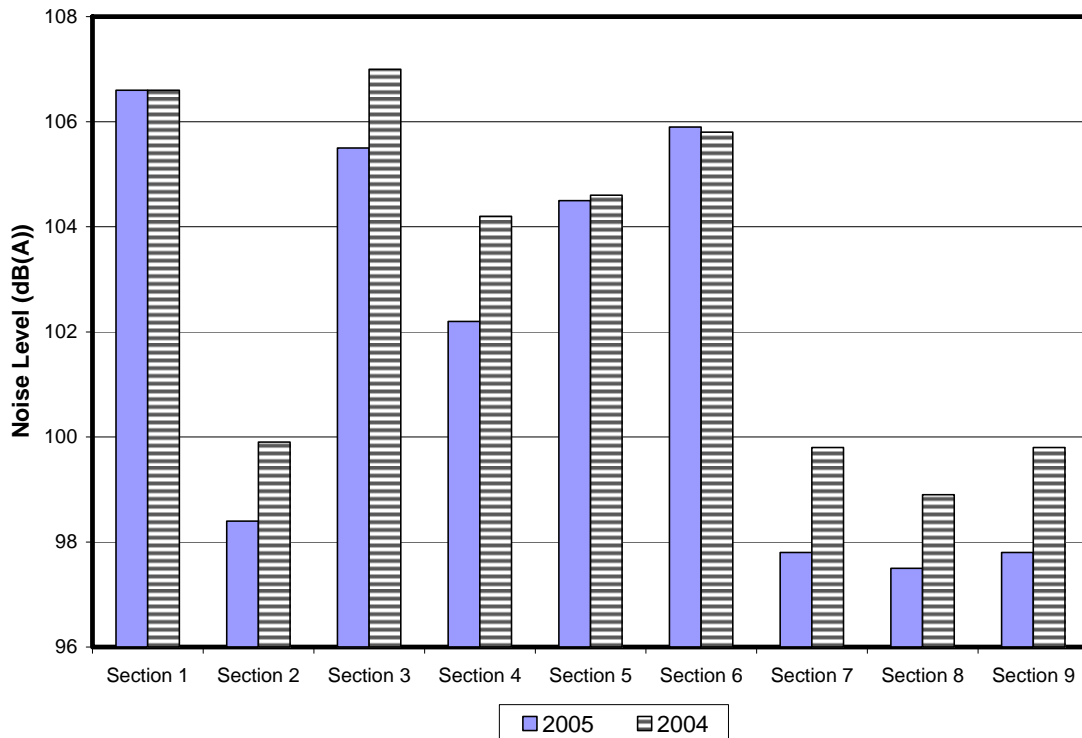


Figure 5. Comparison of the I-70 Test Data for 2004 and 2005

CONCLUSIONS AND RECOMMENDATIONS

Based on the testing conducted in this study and the studies done in 2003, 2004 and 2005 it appears that the noise level of Colorado pavements does increase with time, but very slowly, and that the increase will vary with the pavement surface. It is recommended that the Colorado DOT continue monitoring the noise levels of its pavement surfaces.

APPENDIX A

Tires Used for Testing



Figure A:1. Goodyear Aquatred



Figure A:2. Uniroyal TigerPaw

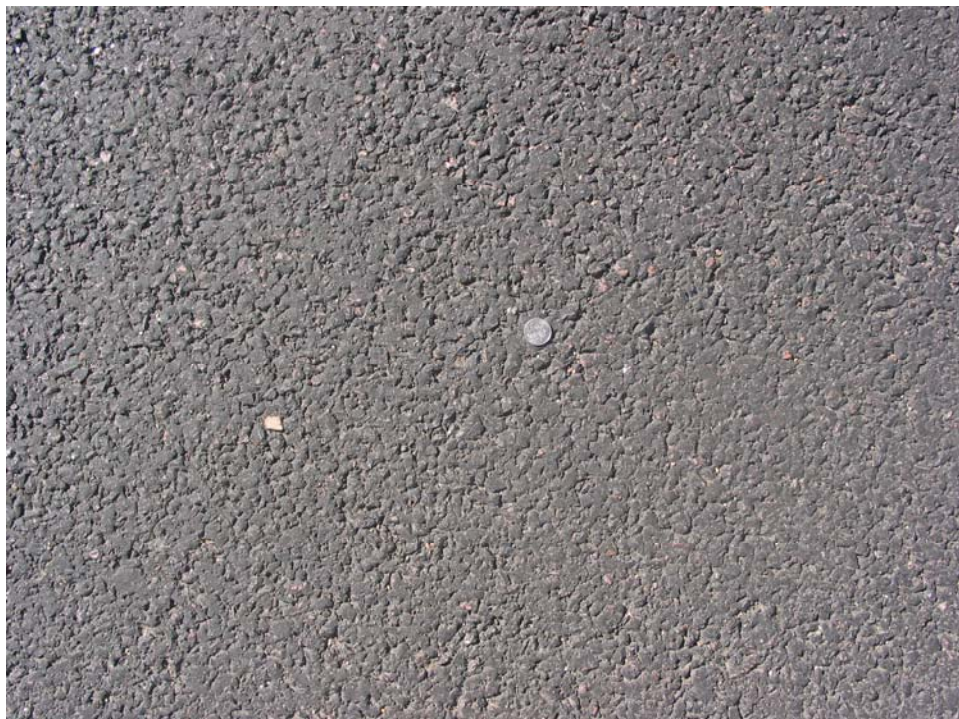
APPENDIX B

Pavement Sites

**Colorado Site 1 (NovaChip)
C 58 Mile Marker 2 - 3 (101.1 dB(A))**



Colorado Site 2 (SMA)
US 83N Mile Marker 57 - 58 (99.6 dB(A))



**Colorado Site 3 (SMA 3/4 inch)
I-70W Mile Marker 272 - 271 (99.7 dB(A))**



**Colorado Site 4 (Longitudinally Tined PCCP)
US 285S Mile Marker 243 - 242 (100.0 dB(A))**



**Colorado Site 5 (Diamond Ground PCCP)
US 285S Mile Marker 245 - 244 (100.7 dB(A))**



**Colorado Site 6 (3/8 inch SMA)
C 74E Brookline to Elk Meadows (97.7 dB(A))**



**Colorado Site 7 (Longitudinally Tined PCCP)
I-25S Mile Marker 231 - 230 (98.2 dB(A))**



**Colorado Site 8 (1/2 inch SX)
US 85S Mile Marker 189 - 188 (98.3 dB(A))**



**Colorado Site 10 (1/2 inch SX)
I – 70W Mile Marker 222 – 221 (96.4 dB(A))**



**Colorado Site 11 (3/4 inch S)
C 470E Mile Marker 5 - 6 (101.1 dB(A))**



Colorado Site 12 (3/4 inch S)

US 287S Mile Marker 262 - 261 (98.2 dB(A))



**Colorado Site 13 (Grooved PCCP)
I-25N Mile Marker 143 - 144 (98.2 dB(A))**



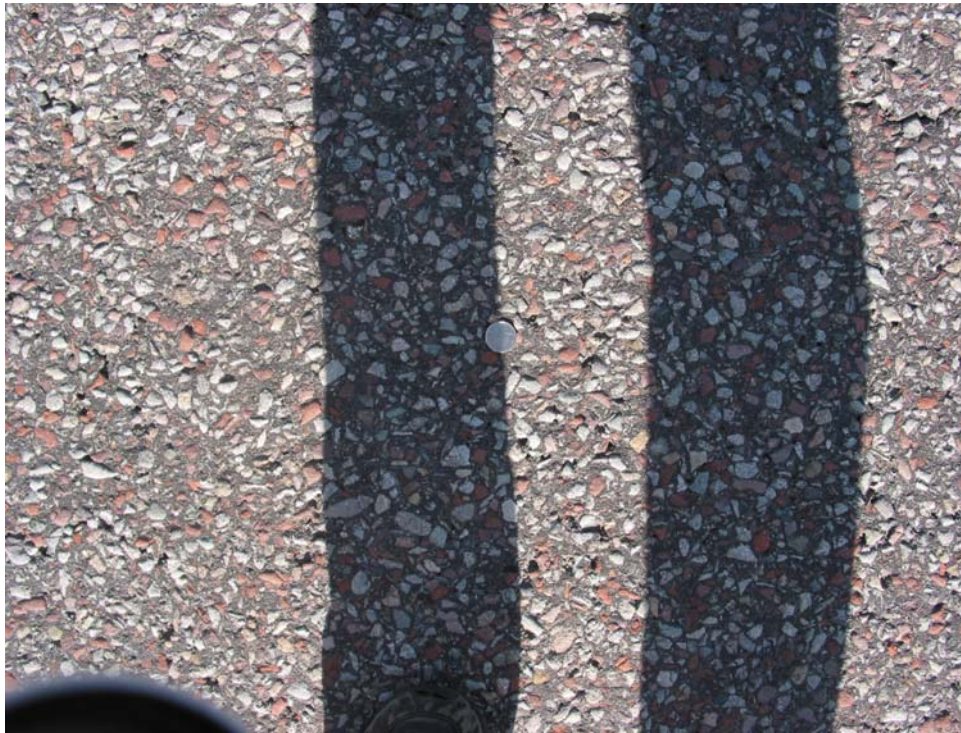
**Colorado Site 14 (1/2 in SMA)
US 50W Mile Marker 48 - 47 (97.4 dB(A))**



**Colorado Site 15 (1/2 in SX)
US 50E Mile Marker 47 - 48 (98.2 dB(A))**



**Colorado Site 16 (NovaChip)
US 82E Mile Marker 32 - 33 (99.9 dB(A))**



**Colorado Site 17 (Carpet Drag PCCP)
C 121 S Mile Marker 2 – 1.5 (99.4 dB(A))**



**Colorado Site 19 (SMA 3/4)
I - 70W Mile Marker 252 - 251 (99.7 dB(A))**



**Colorado Site 20 (Carpet Drag PCCP)
I-70 Mile Marker 91.75 (500 feet) (97.5 dB(A))**



Colorado Site 21 (SMA)
I-70W Mile Marker 142 - 141 (98.5 dB(A))



**Colorado Site 22 (Diamond Ground PCCP)
I-70W Mile Marker 142 - 141 (98.5 dB(A))**



**Colorado Site 23 – 1
(Transverse 1" Tining)
I-70 PCCP Texture Test Sections (106.6 dB(A))**



**Colorado Site 23 – 2
(Transverse Astro-turf – No Tining)
I-70 PCCP Texture Test Sections (98.4 dB(A))**



**Colorado Site 23 – 3
(Longitudinal Astro Turf/Transverse Random Tining)
I-70 PCCP Texture Test Sections (105.5 dB(A))**



**Colorado Site 23 – 4
(Longitudinal Astro-Turf/Transverse ½ in. Tining)
I-70 PCCP Texture Test Sections (102.2 dB(A))**



**Colorado Site 23 – 5
(Longitudinal Astro-Turf/Transverse Random Tinning)
I-70 PCCP Texture Test Sections (104.5 dB(A))**



**Colorado Site 23 – 6
(Longitudinal Astro Turf/Transverse 1 in Tining)
I-70 PCCP Texture Test Sections (105.9 dB(A))**



**Colorado Site 23 – 7
(Longitudinal Astro Turf/Longitudinal Sawing $\frac{3}{4}$ in)
I-70 PCCP Texture Test Sections (97.8 dB(A))**



**Colorado Site 23 – 8
(Longitudinal Astro Turf/No Tining)
I-70 PCCP Texture Test Sections (97.5 dB(A))**



**Colorado Site 23 – 9
(Longitudinal Astro Turf/Transverse 3/4 in Tining)
I-70 PCCP Texture Test Sections (97.8 dB(A))**

