**Report No. CDOT-2006-18**
**Final Report**

# 2005 COLORADO DOT TIRE/PAVEMENT NOISE STUDY

**Douglas I. Hanson**
**Brian Waller**


**November 2006**

**COLORADO DEPARTMENT OF TRANSPORTATION**
**RESEARCH BRANCH**

# DISCLAIMER

The contents of this report reflect the views of the author(s), who is (are) responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Transportation, National Center for Asphalt Technology, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

# TECHNICAL REPORT DOCUMENTATION PAGE

| | | |
|---|---|---|
| 1. Report No.<br>CDOT-2006-18 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>2005 COLORADO DOT TIRE/PAVEMENT NOISE STUDY | | 5. Report Date<br>November 2006 |
| | | 6. Performing Organization Code |
| 7. Author(s)<br>Douglas I. Hanson, Brian Waller | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>National Center for Asphalt Technology<br>Auburn University<br>277 Technology Parkway<br>Auburn, AL 36830 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>Colorado Department of Transportation –Research<br>4201 E. Arkansas Ave.<br>Denver, CO 80222 | | 13. Type of Report and Period Covered<br>Final |
| | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes<br>Prepared in cooperation with the US Department of Transportation, Federal Highway Administration | | |


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.


| | | | |
|---|---|---|---|
| 17. Keywords<br>traffic noise, surface texture, acoustic energy, close-proximity noise testing | 18. Distribution Statement<br>No restrictions. This document is available to the public through:<br>National Technical Information Service<br>Springfield, VA 22161 | | |
| 19. Security Classif. (of this report)<br>None | 20. Security Classif. (of this page)<br>None | 21. No. of Pages<br>48 | 22. Price |

**Form DOT F 1700.7** (8-72) Reproduction of completed page authorized

# COLORADO DOT TIRE/PAVEMENT NOISE STUDY

By

Douglas I. Hanson
Assistant Director
National Center for Asphalt Technology

Brian Waller
Laboratory Engineer
National Center for Asphalt Technology

Report No.
CDOT-2006-18

Prepared by
National Center for Asphalt Technology
Auburn University
277 Technology Parkway
Auburn, Alabama 36830

Sponsored by the
Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

November 2006

Colorado Department of Transportation
Research Branch
4201 E. Arkansas Ave.
Denver, CO 80222
(303) 757-9506

# 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.

# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

## 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 Asssociation (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.

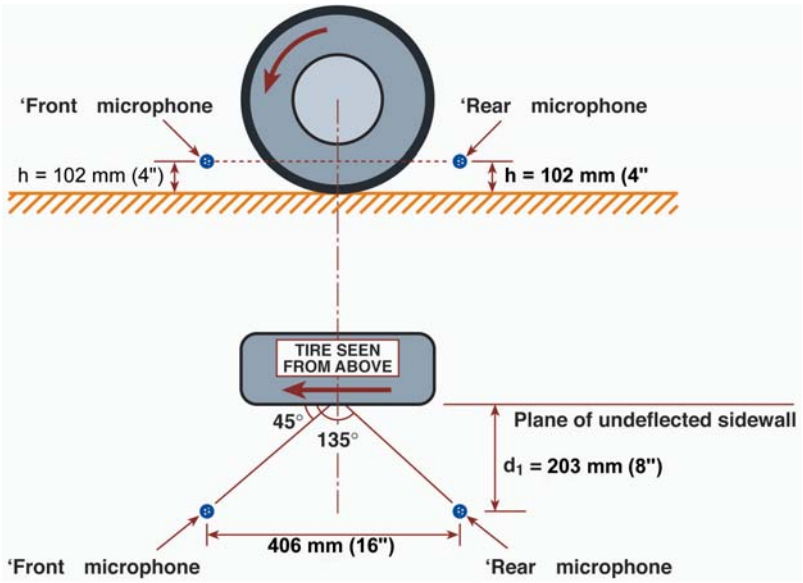



**Figure 2. Diagram Showing Microphone Locations on NCAT CPX Trailer**

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 |

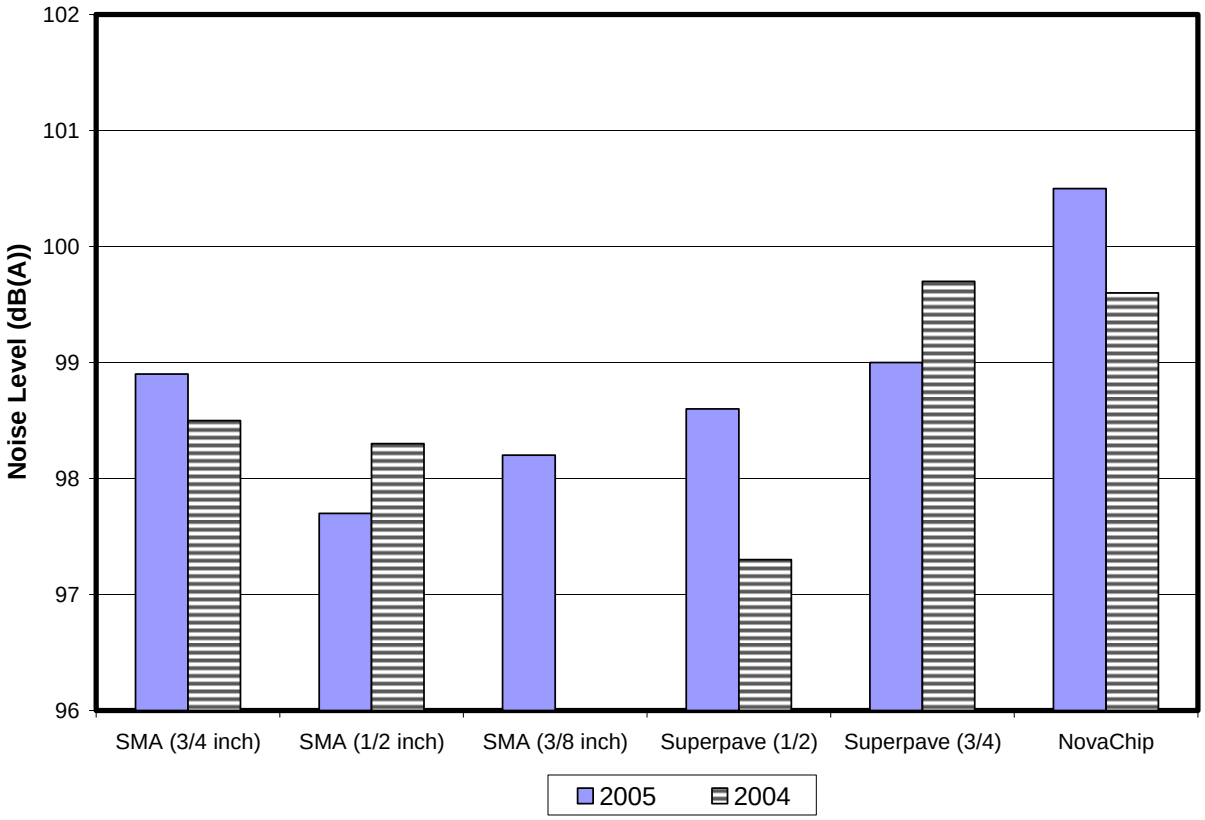



**Figure 3. Comparison of HMA Test Data for 2004 and 2005**

## 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 | - | - |
| | | | 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.

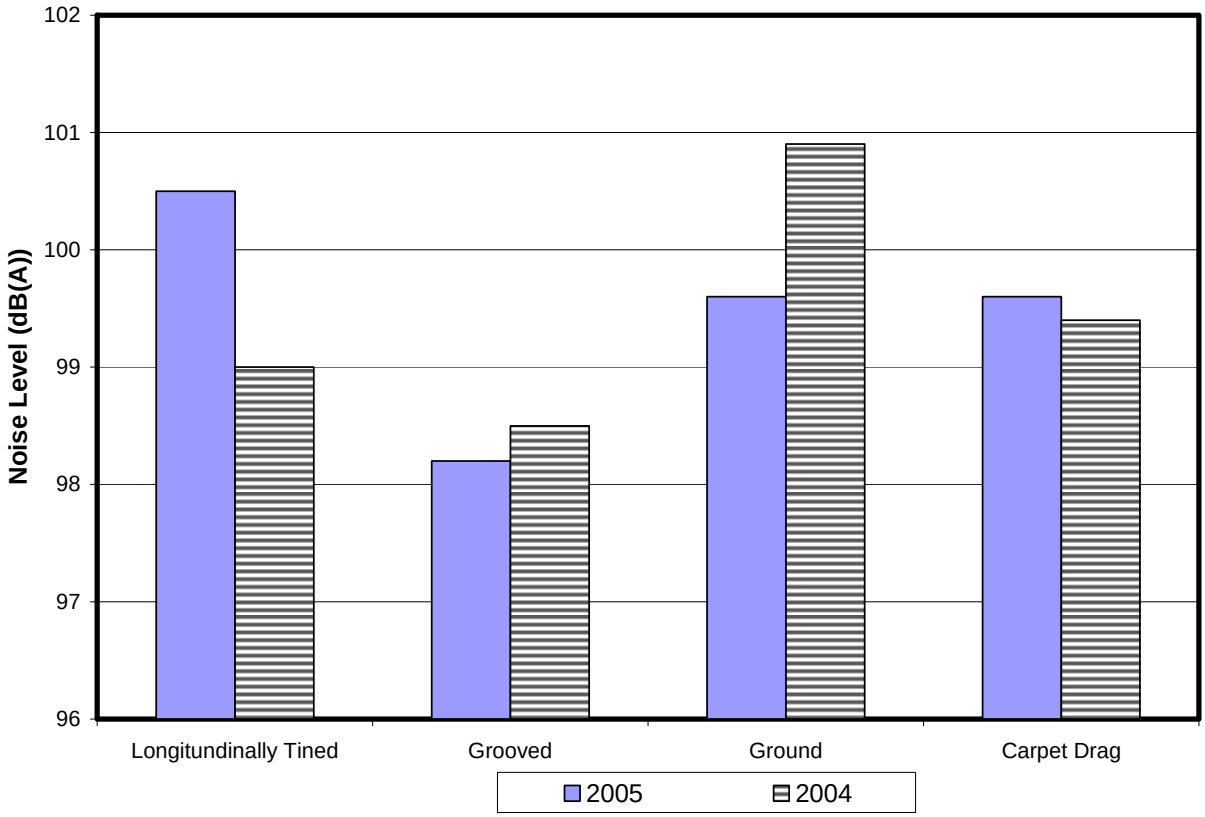



**Figure 4. Comparison of PCCP Test Data for 2004 and 2005**

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

| Section | Length | Type of Texture | Noise Level dB(A) | |
|---|---|---|---|---|
| | | | 2005 | 2004 |
| 1<br>MP 335.3 | 2800 | Transverse 1” Tining | 106.6 | 106.6 |
| 2 | 2500 | Transverse Astro-turf<br>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<br>MP 338.3 | 1000 | Longitudinal Astro-Turf /Longitudinal 3/4 “ Tining | 97.8 | 99.8 |
| Average of all surfaces | | | 101.8 | 102.9 |

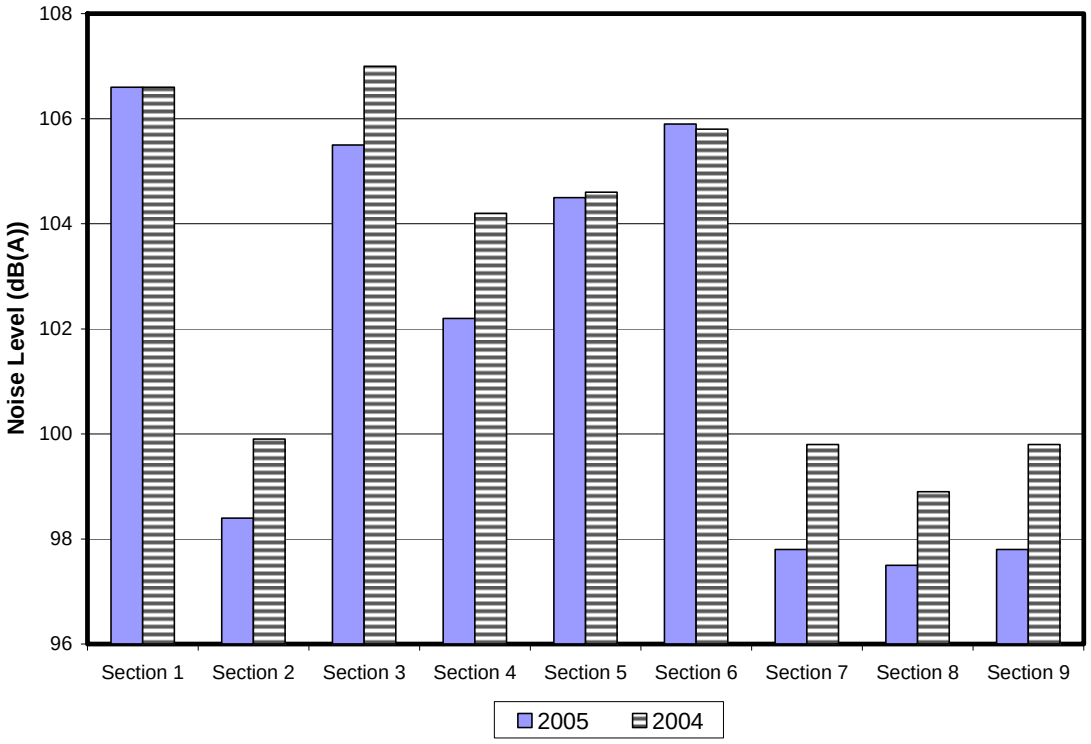



**Figure 5. Comparison of the I-70 Test Data for 2004 and 2005**

## 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

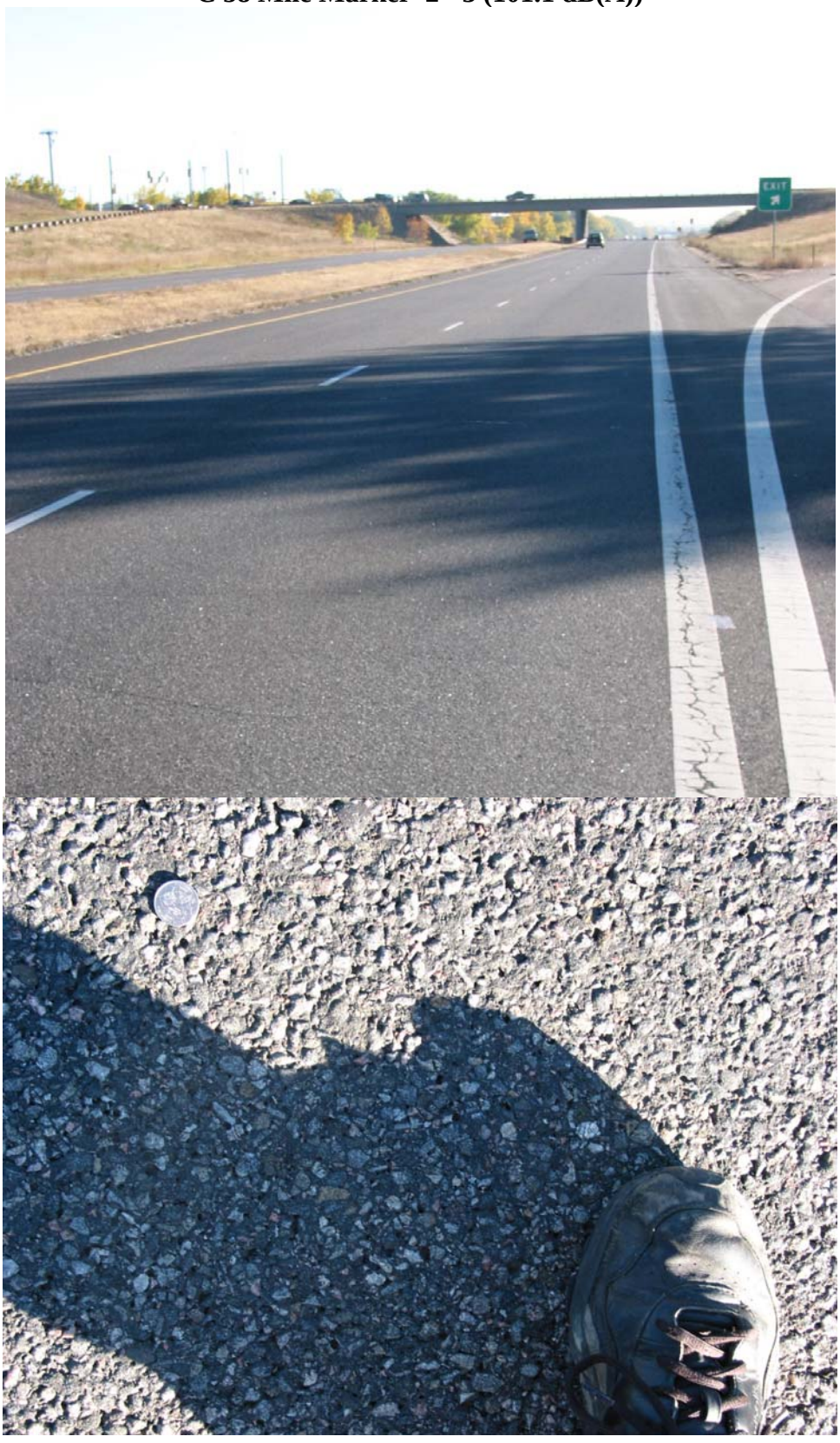
**Figure A:1. Goodyear Aquatred**

**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))**

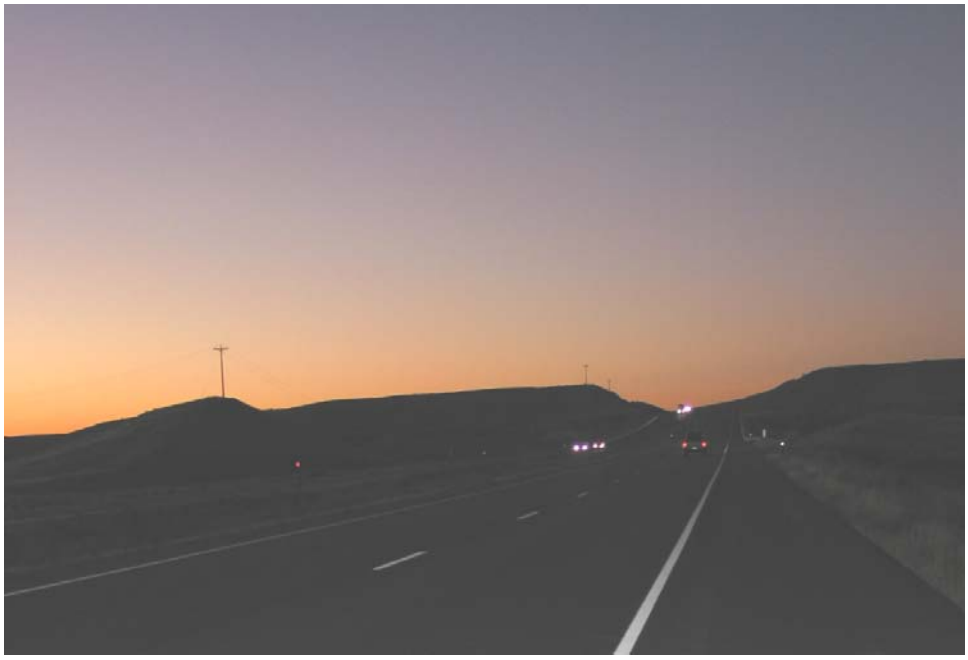
**Colorado Site 11 (3/4 inch S)**
**C 470E Mile Marker 5 - 6 (101.1 dB(A))**

**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))**

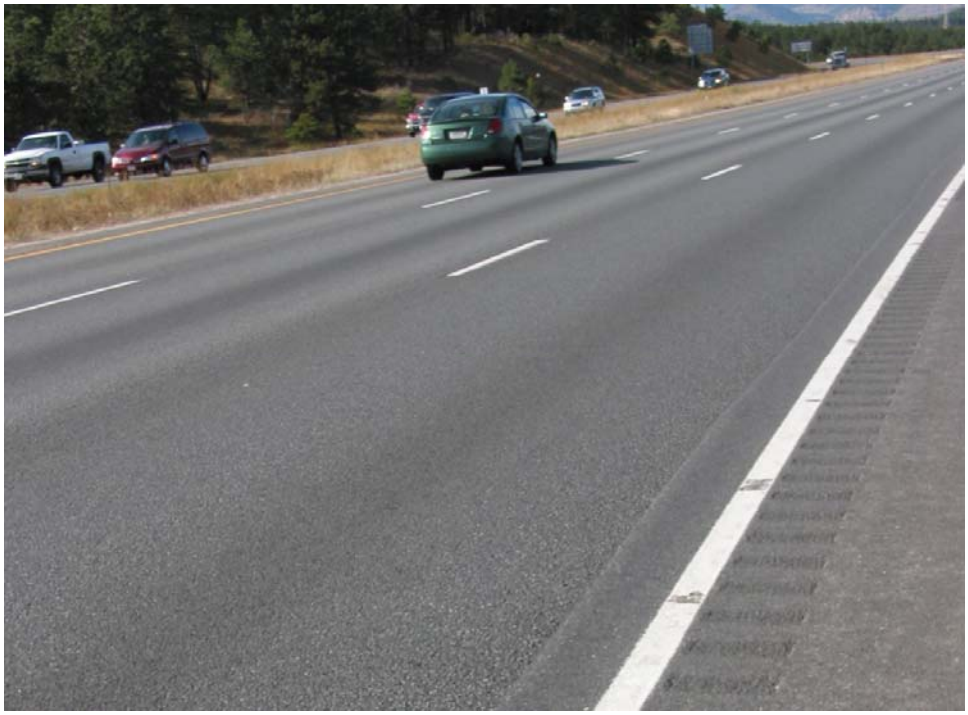


**Colorado Site 15 (1/2 in SX)**
**US 50E Mile Marker 47 - 48 (98.2 dB(A))**

**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))**

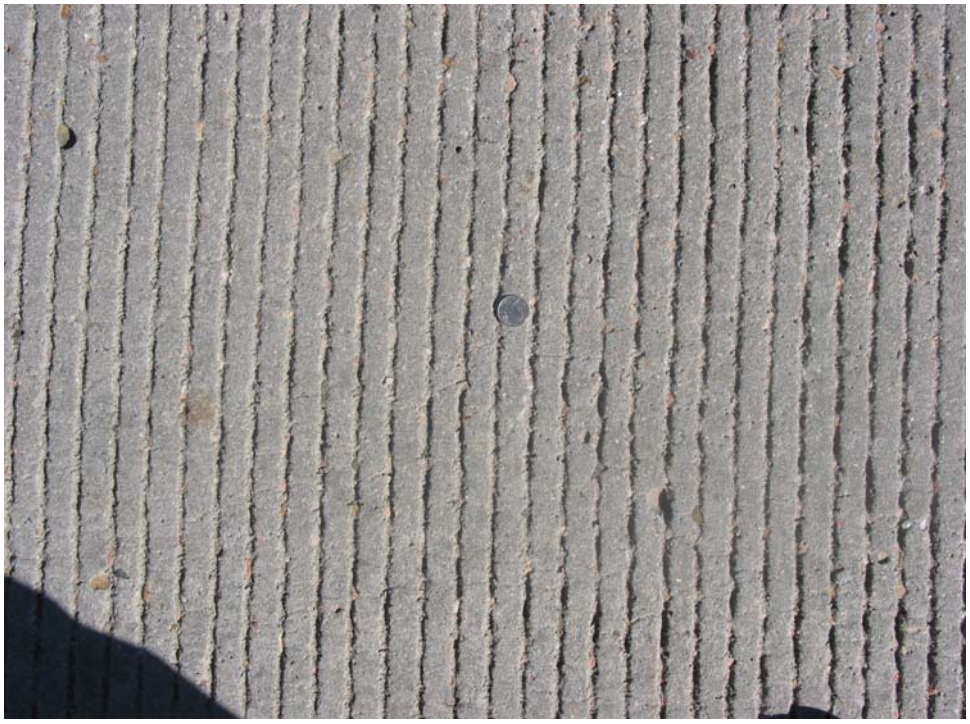


**Colorado Site 20 (Carpet Drag PCCP)**
**I-70 Mile Marker 91.75 (500 feet) (97.5 dB(A))**

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

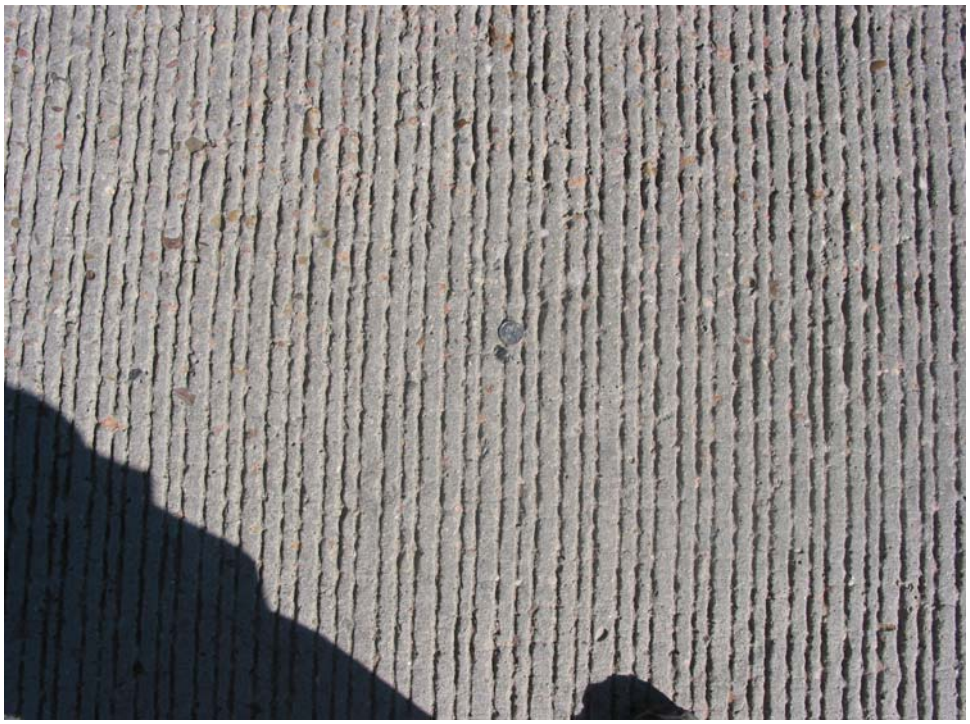
**Colorado Site 22 (Diamond Ground PCCP)**
**I-70W Mile Marker 142 - 141 (98.5 dB(A))**

**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 inTining)**
**I-70 PCCP Texture Test Sections (105.9 dB(A))**

**Colorado Site 23 – 7**
**(Longitudinal Astro Turf/Longitudinal Sawing ¾ 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 inTining)**
**I-70 PCCP Texture Test Sections (97.8 dB(A))**