Concrete Pavement Noise

I-90 Spokane, I-90 Easton, I-5 Federal Way, I-82 Sunnyside, and I-5 Northgate

WA-RD 814.1

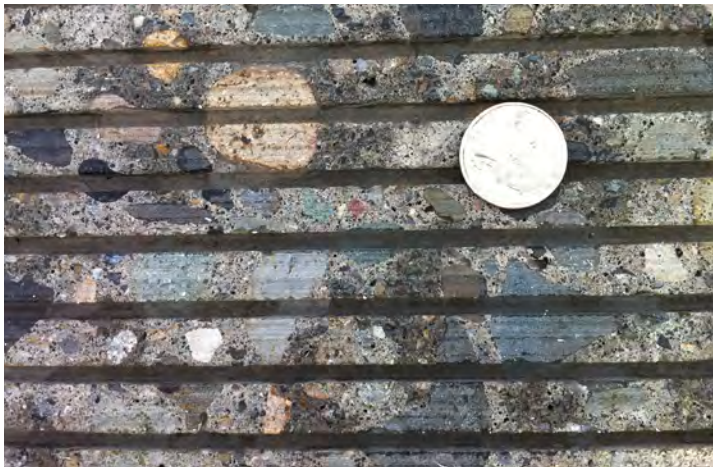
Keith Anderson
Tim Sexton
Jeff Uhlmeyer
Mark Russell
Jim Weston

July 2013

Carpet Drag Texture

Longitudinal Tined Texture

Diamond Grinding



Next Generation Concrete Surface

Washington State Department of Transportation
Office of Research & Library Services

WSDOT Research Report

Special Project Report

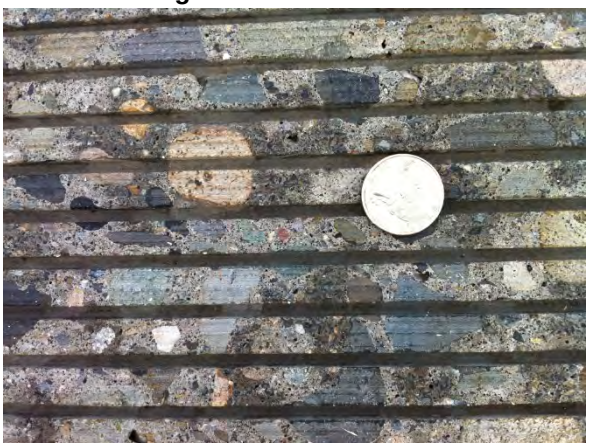
Concrete Pavement Noise

I-90 Spokane, I-90 Easton, I-5 Federal Way, I-82 Sunnyside, and I-5 Northgate

Carpet Drag Texture

Longitudinal Tined Texture

Diamond Grinding



Next Generation Concrete Surface

Washington State Department of Transportation

Engineering and Regional Operations
Construction Division
State Materials Laboratory

Special Project Report

REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 814.1		

4. TITLE AND SUBTITLE	5. REPORT DATE
Concrete Pavement Noise	July 2013
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Keith W. Anderson, Tim Sexton, Jeff S. Uhlmeyer, Mark Russell and Jim Weston	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Department of Transportation	
Materials Laboratory, MS-47365	11. CONTRACT OR GRANT NO.
Olympia, WA 98504-7365	

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Washington State Department of Transportation Transportation Building, MS 47372	Final Report
Olympia, Washington 98504-7372	14. SPONSORING AGENCY CODE
Project Manager: Kim Willoughby, 360-705-7978	

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

On-Board Sound Intensity (OBSI) measurements are reported for various concrete pavement textures including transverse and longitudinal tining, carpet drag, conventional diamond grinding and Next Generation Concrete Surface. The noise levels increased on most of the textures to levels in the 104 to 108 dBA range. The cause of the increased noise levels was attributed to the wear on the pavements from studded tires.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Concrete pavement, longitudinal tining, transverse tining, carpet drag, Next Generation Concrete Surface, On-Board Sound Intensity	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	26	

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

Introduction

The Washington State Department of Transportation (WSDOT) has been evaluating new types of pavement and texturing processes with the potential to reduce the amount of freeway noise generated from the interaction of tires rolling across pavement. Other state DOT's have successfully used rubber modified Open Graded Friction Course (OGFC) hot mix asphalt pavements to reduce tire/pavement noise. The American Concrete Paving Association (ACPA) and International Grooving and Grinding Association (IGGA) have supported the development and implementation of a new grinding process for concrete pavements called the Next Generation Concrete Surface (NGCS) which has also been shown to reduce tire/pavement noise. Both of these options have been used on trial installations in Washington between 2006 and 2010. Three OGFC projects were constructed on high volume roadways in the Seattle urban area between 2006 and 2009. A section of NGCS was installed on I-82 near Sunnyside, Washington in October 2010.

On-Board Sound Intensity (OBSI) equipment was acquired in early 2006 for the evaluation of these potentially quieter pavements. The OBSI method isolates tire-pavement noise by measuring sound levels just three inches above where the tire meets the pavement. Three measurements were collected within each test section and results for each date are the average of these three measurements. To evaluate performance for the full test section, unique locations were measured during each collection period, instead of repeating measurements at the same location within the section. This method is a likely contributor to the variability in the results.

The three hot-mix asphalt OGFC sections were unsuccessful in maintaining noise levels that were audibly quieter than conventional dense graded hot-mix asphalt pavements (report links in Reference section). This document reports the noise results from the NGCS trial section and other concrete pavement projects with carpet drag, transverse tining, longitudinal tining, and conventional diamond ground textures. The results are organized by roadway/location. A summary of the observations and conclusions are provided at the end of the document.

I-90 Spokane

Concrete is the pavement choice required by the lowest life cycle cost decision process for the Spokane area due to high traffic volumes. The Eastern Region has the state's highest percentage of vehicles using studded tires, therefore, concrete pavements have been favored by the Region's engineers. A number of projects were tested with transverse tined and carpet drag textures on I-90 between MP 284 and MP 292, as shown on the location map in Figure 1. The first series of On-Board Sound Intensity (OBSI) tests were performed on the transverse tined projects between MP 284.55 and MP 287.99 which includes the following contracts.

- Contract 5438, Sprague Avenue Interchange Phase 2 (completed in 2000)
- Contract 5637, Sprague Avenue to Argonne Road (completed in 2000)
- Contract 5947, Sprague Avenue Interchange Phase 3 (completed in 2001)

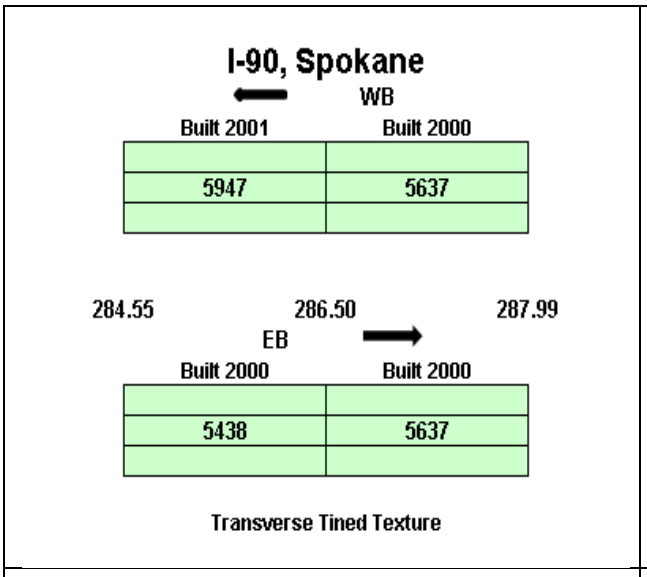


Figure 1. I-90 projects with transverse tined construction texture.

Figure 2. Transverse tined texture (location unknown).

Transverse Tining

The three projects with transverse tined texture were initially tested in October 2006 when they were between six and seven years in age. Figure 2 is a photo of a newly constructed

transverse tined texture similar to what was applied on these sections. The noise readings were very consistent over the seven year monitoring period (2006-2013). Values ranged between 107.1 and 109.0 A-weighted decibels (dBA) with an average of 107.6 dBA (Figure 3). The March 2011 test at 109.0 dBA and April 2013 reading at 108.6 dBA seem to deviate from the trend of the other readings that were in a tight range between 107.1 and 107.5 dBA. The OBSI test results support the assumption that the transverse tined texture had been removed by studded tire wear prior to the initiation of testing, an assumption that was confirmed by visual field inspection.

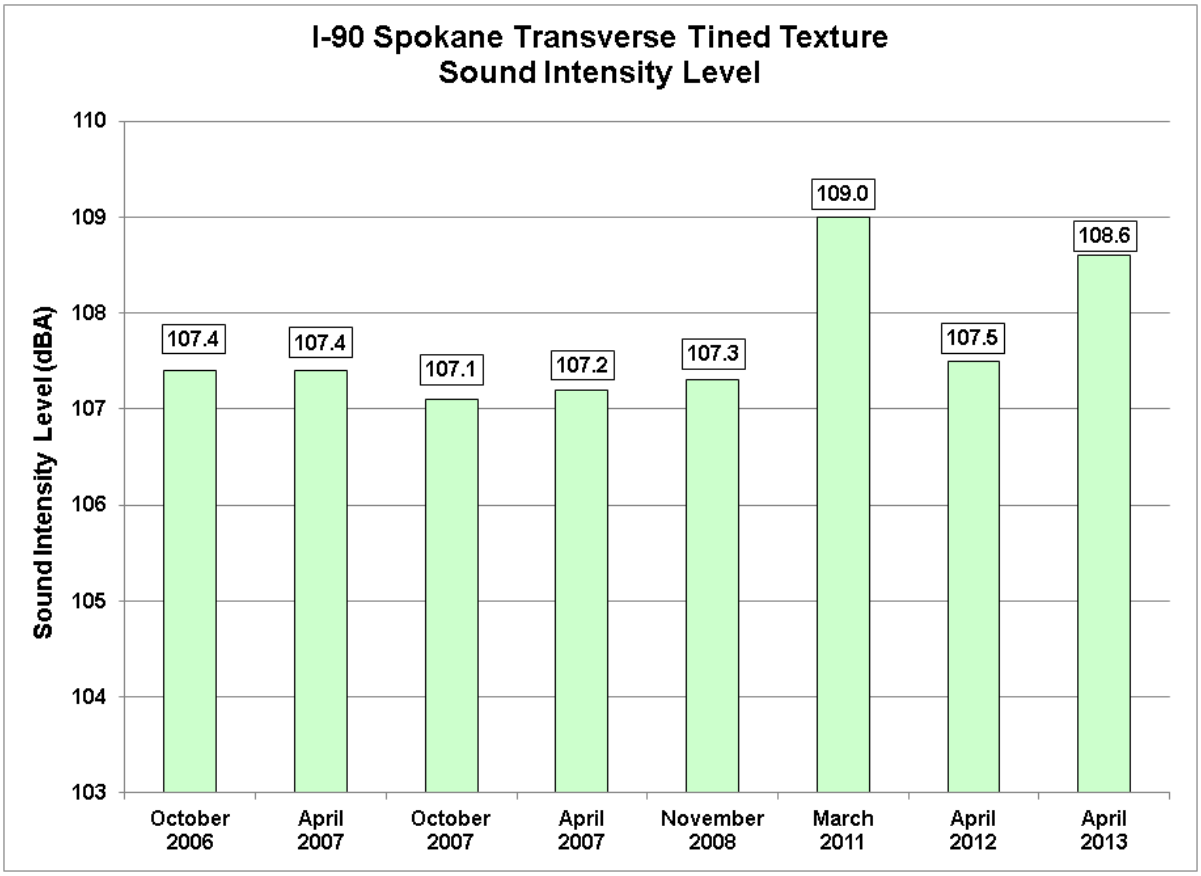


Figure 3. Sound intensity level data for transverse tined concrete on I-90 near Spokane.

Carpet Drag

The project located east of the transverse tined projects was one of the first built using a carpet drag texture. The project included a number of experimental mix designs including 800 psi flexural strength, Hard-Cem additive, and 925 lbs/yd cement content (Figure 4). The carpet drag finish was inserted into the contract as a change order and did not include an enforceable specification for the depth of the carpet drag texture. As a result, the texture depth did not meet the 1.0 mm minimum standard normally required for a carpet drag finish (Figure 5).

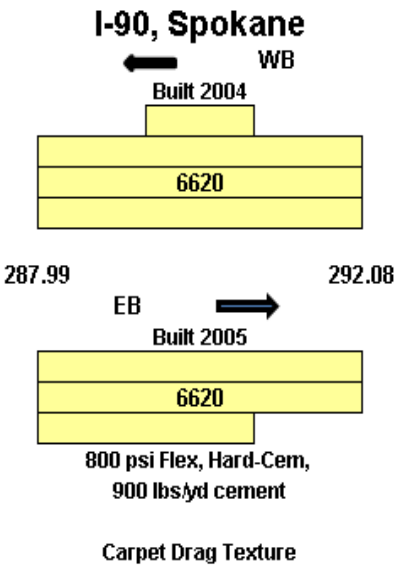


Figure 4. I-90 Spokane project with carpet drag texture.

Figure 5. Shallow carpet drag texture on I-90 Spokane project.

OBSI testing began in October of 2006 when the pavements were between one and two years in age (Figure 6). The initial measurements in October 2006 were 106.1 dBA and gradually decreased to 104.0 dBA in October of 2007. In April of 2013, OBSI values then increased to 107.4 dBA. The March 2011 and April 2013 readings are not in line with the general trend of the other readings similar to the previously discussed transverse tined section. Since the OBSI measurements for both the transverse tined and carpet drag sections were obtained on the same

day on both the transverse tined and carpet drag sections, possible explanations for the higher readings could be a metrological anomaly or a problem with the noise measurement equipment that went unidentified during the post-measurement calibration.

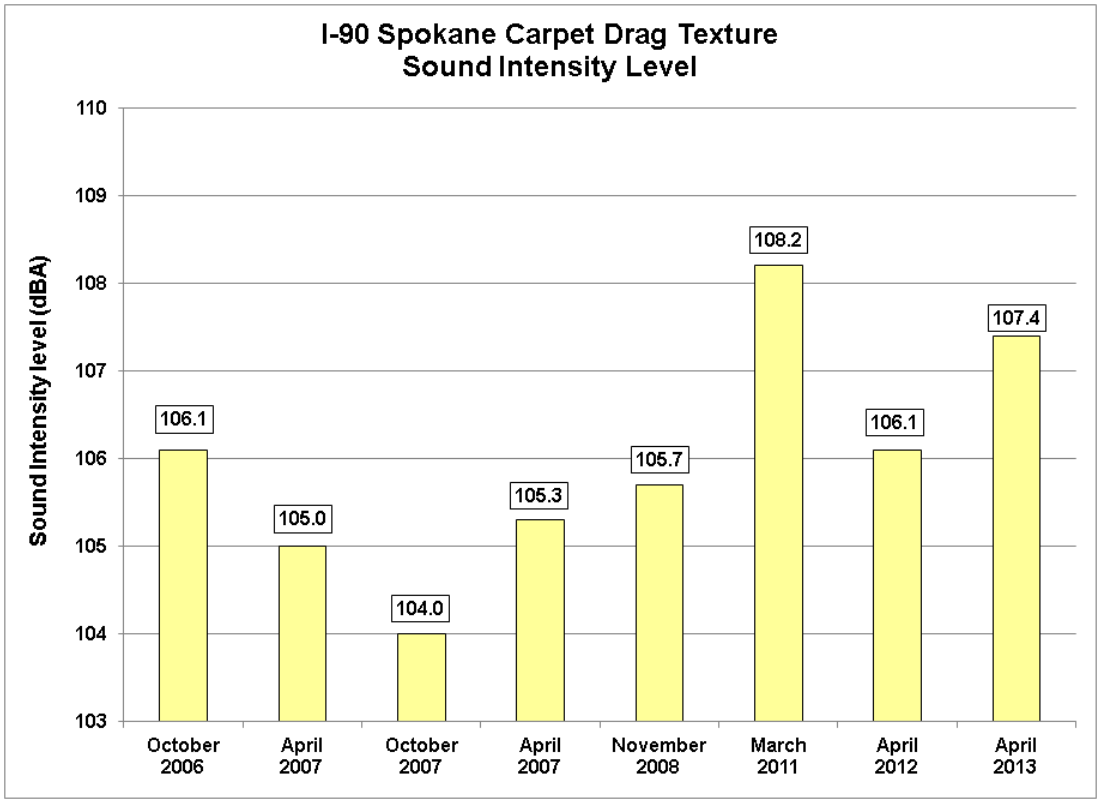


Figure 6. I-90 Spokane noise data for carpet drag texture.

I-90 Easton

In 2010 a project was constructed on I-90 near Easton that replaced the right hand travel lane with new concrete using a longitudinal tined texture. Severely cracked panels in the left hand passing lane were replaced and the lane was diamond ground to improve the ride and extend the life of the pavement. The project limits were from MP 70.60 to MP 79.00 (Figure 7).

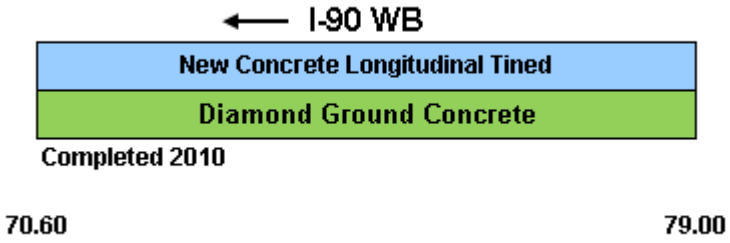


Figure 7. I-90 Easton project with longitudinal tining and diamond ground texture.

Longitudinal Tining

The initial noise level on the longitudinal tined lane was 105.0 dBA (Figure 8). The noise level ranged from 104.0 to 106.2 dBA with an average of 105.0 dBA. Again, there is not a clear trend in the pattern of the readings. The average noise level of the longitudinal tining pavement is 2.3 dBA noisier than the old pavement that it replaced. Photos of longitudinal tining are found on page 10 in the discussion of the I-5 Federal Way projects.

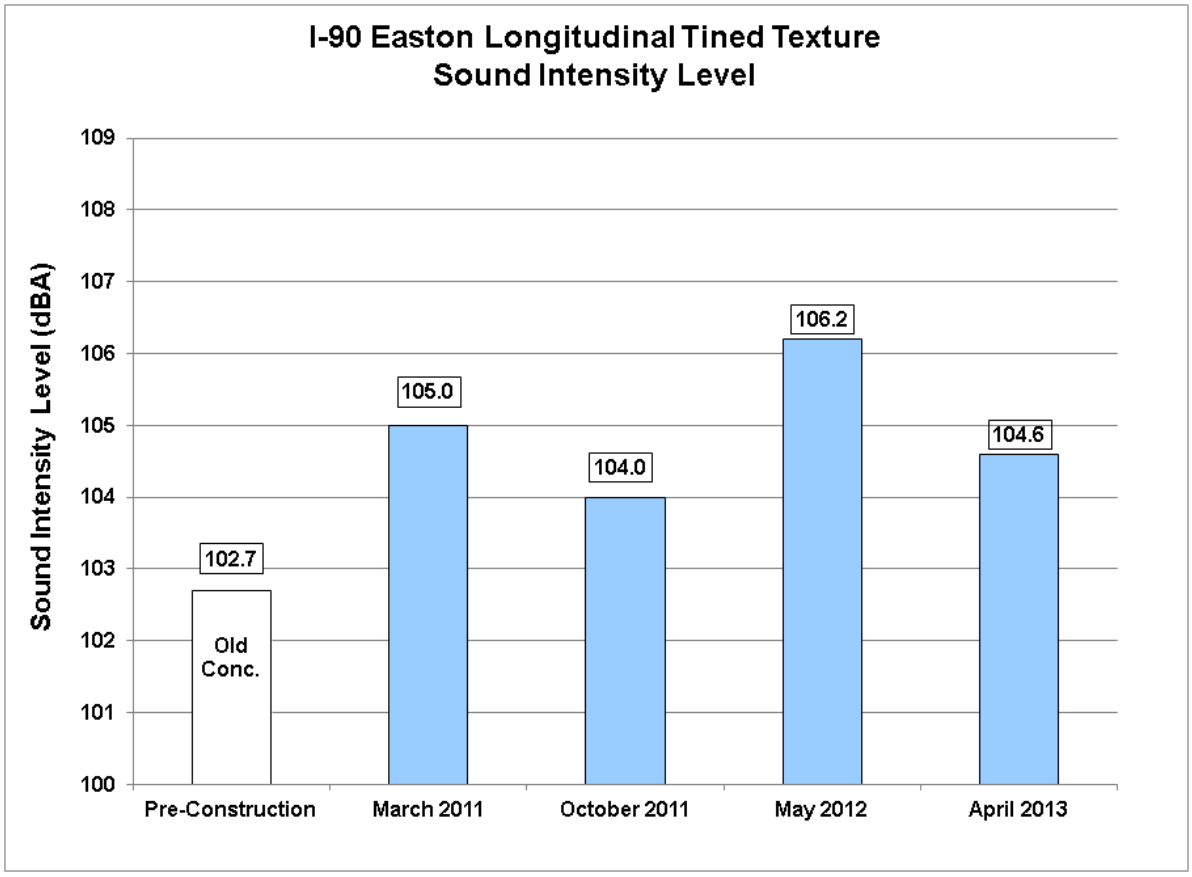


Figure 8. Sound intensity level data for longitudinal tined concrete on I-90 near Easton.

Conventional Diamond Grinding (CDG)

The noise level on the left hand passing lane prior to diamond grinding in 2010 was 102.5 dBA. The first measurement on the diamond ground lane was 105.4 dBA in March of 2011 (Figure 9). The noise level gradually increased to a peak of 106.4 dBA in May of 2012 before decreasing to 103.7 dBA at the final reading in April 2013. The average noise level was 105.4 dBA. The data does not display a clear trend over time or season.

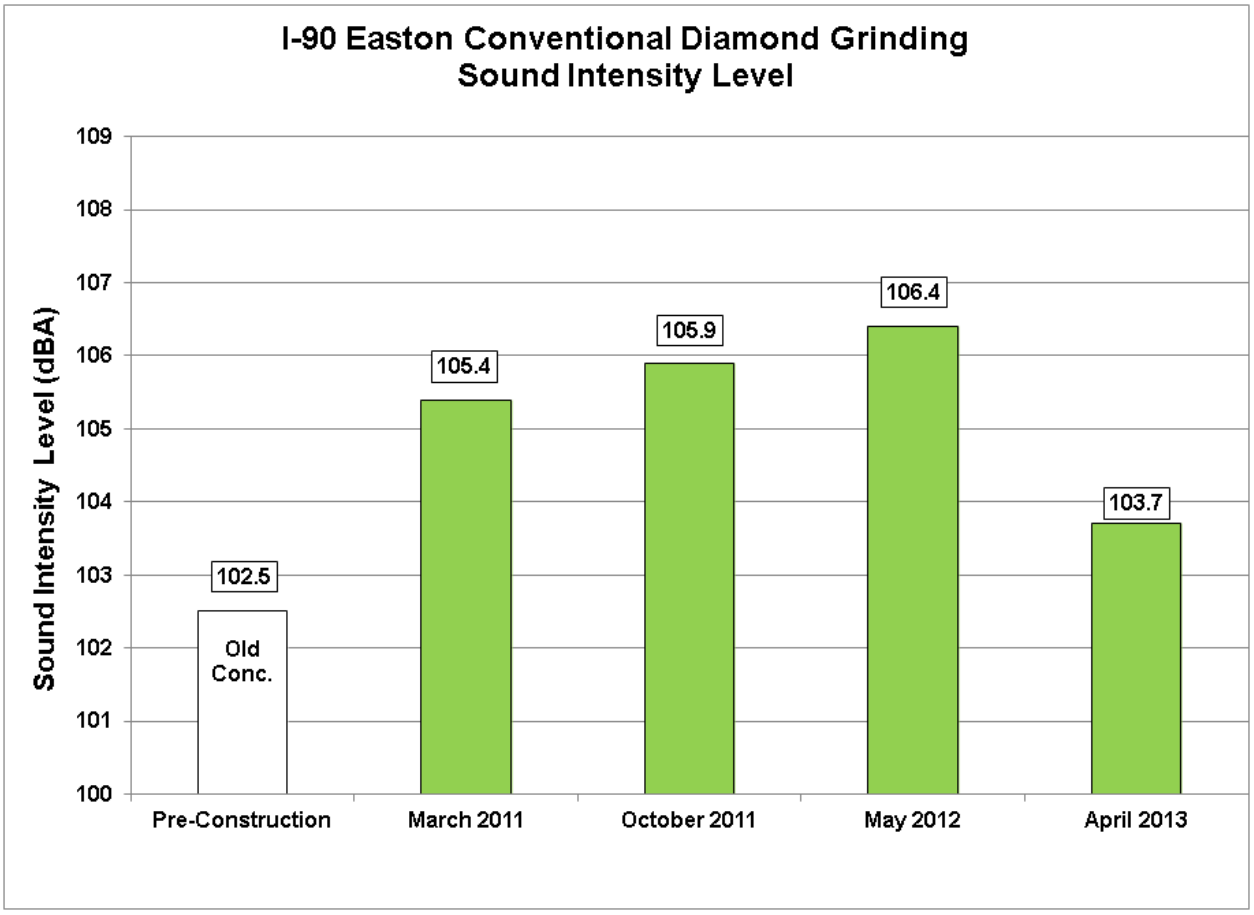


Figure 9. Sound intensity level data for conventional diamond ground concrete on I-90 near Easton.

I-5 Federal Way

Two projects were built on I-5 between Pierce County Line and Federal Way that constructed HOV lanes with various pavement textures. The majority of the pavement received a carpet drag texture, but two short sections of transverse tined texture and a longer section of longitudinal tined texture were also included (Figure 10). The noise readings on this project are more representative of these textures than the Spokane I-90 sections because the measurement began shortly after the projects were open to traffic. Photos from the project (Figures 11-16) show the construction of the carpet drag and longitudinal tined textures.

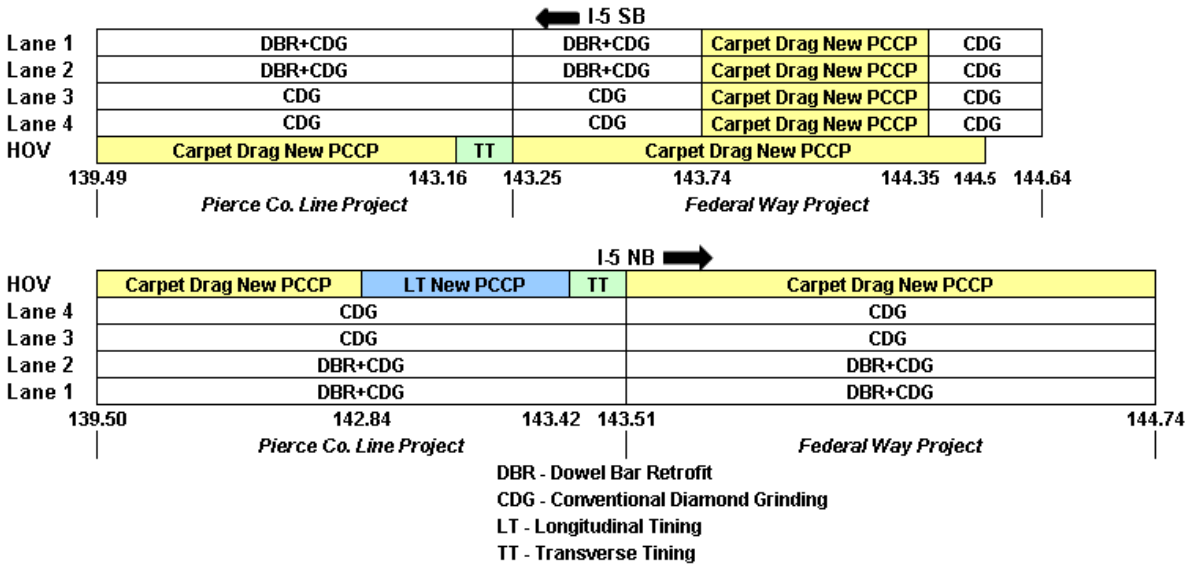


Figure 10. I-5 Federal Way projects with carpet drag, longitudinal and transverse tined texture.

Figure 11. Installation of carpet drag texture on I-5.

Figure 12. I-5 fresh carpet drag texture.

Figure 13. I-5 carpet drag texture.

Figure 14. I-5 carpet drag texture close-up of sand patch text.

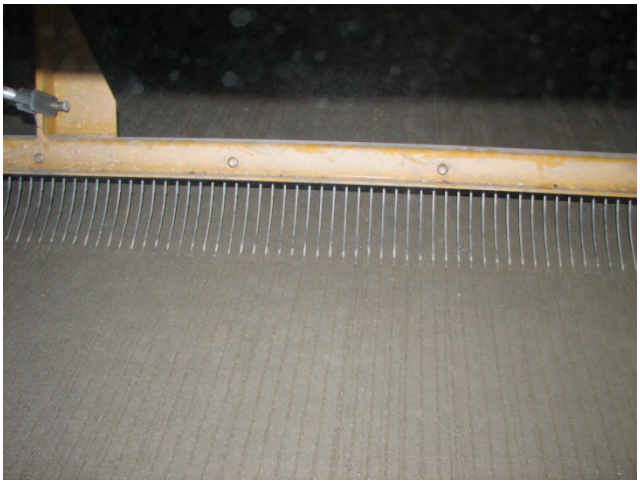


Figure 15. I-5 formation of longitudinal tined texture.

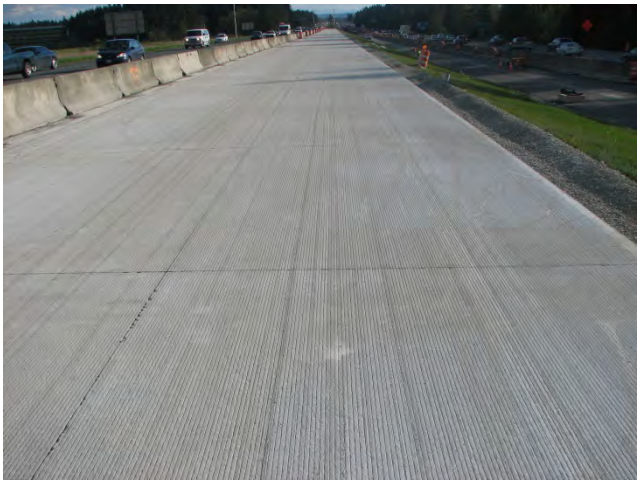


Figure 16. I-5 longitudinal tining close-up.

Carpet Drag

The noise measurements on the two projects began in October of 2006 with additional measurements in April of 2007 and January of 2008. The initial value for the carpet drag sections was 102.2 dBA and it increased to 103.1 dBA in 2007 and to 103.0 dBA in 2008. Noise levels increased slightly with additional traffic wear as show in Figure 17.

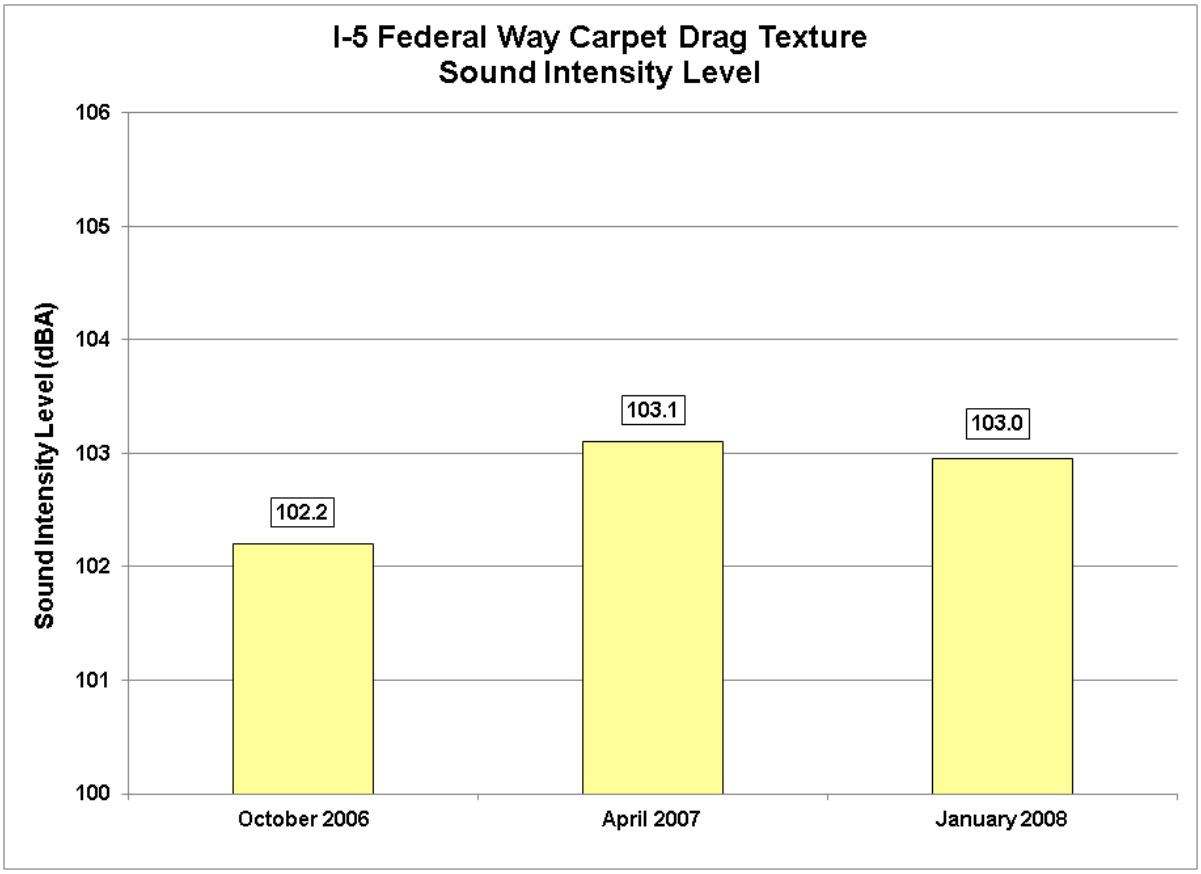


Figure 17. Sound intensity level data for carpet drag textured concrete on I-5 near Federal Way.

Longitudinal Tining

The noise readings for the longitudinal tined section began at 103.8 dBA in 2006, decreasing to 102.4 dBA in 2007, then further decreasing to 102.0 dBA in 2008 as shown in Figure 18. This decrease may be the result of the wearing off of the edges of the grooves that resulted in a flatter surface similar to the profile of a Next Generation Concrete Surface.

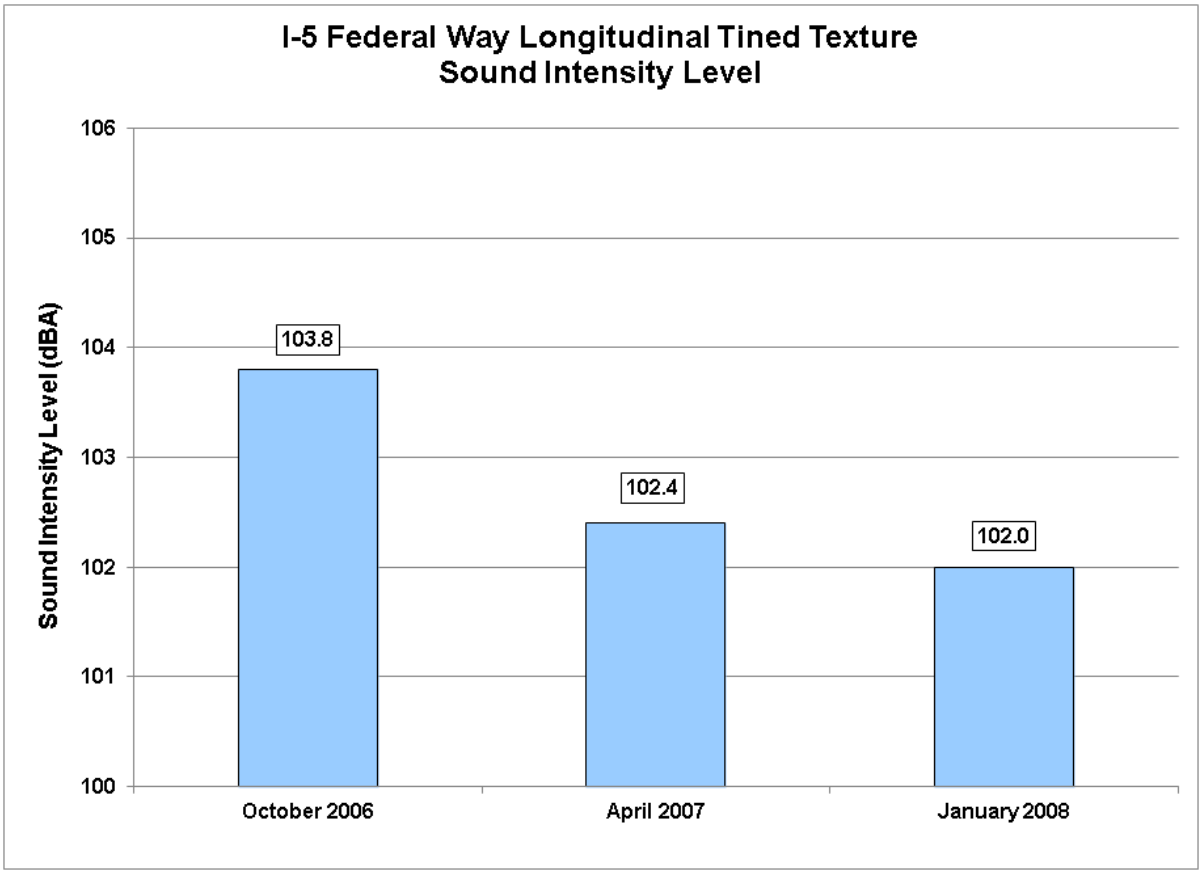


Figure 18. Sound intensity level data for longitudinal tined concrete on I-5 near Federal Way.

Transverse Tining

The transverse tined section noise measurements are shown in Figure 19. After the first reading of 102.7 dBA in 2006 levels increased to 103.5 dBA in 2007, then decreased to 102.3 dBA in 2008. No pattern is discernible to the readings; however, because of the short length of these sections (500 feet) it is possible that the noise measurements were not located entirely on the transverse tining for each of the three readings.

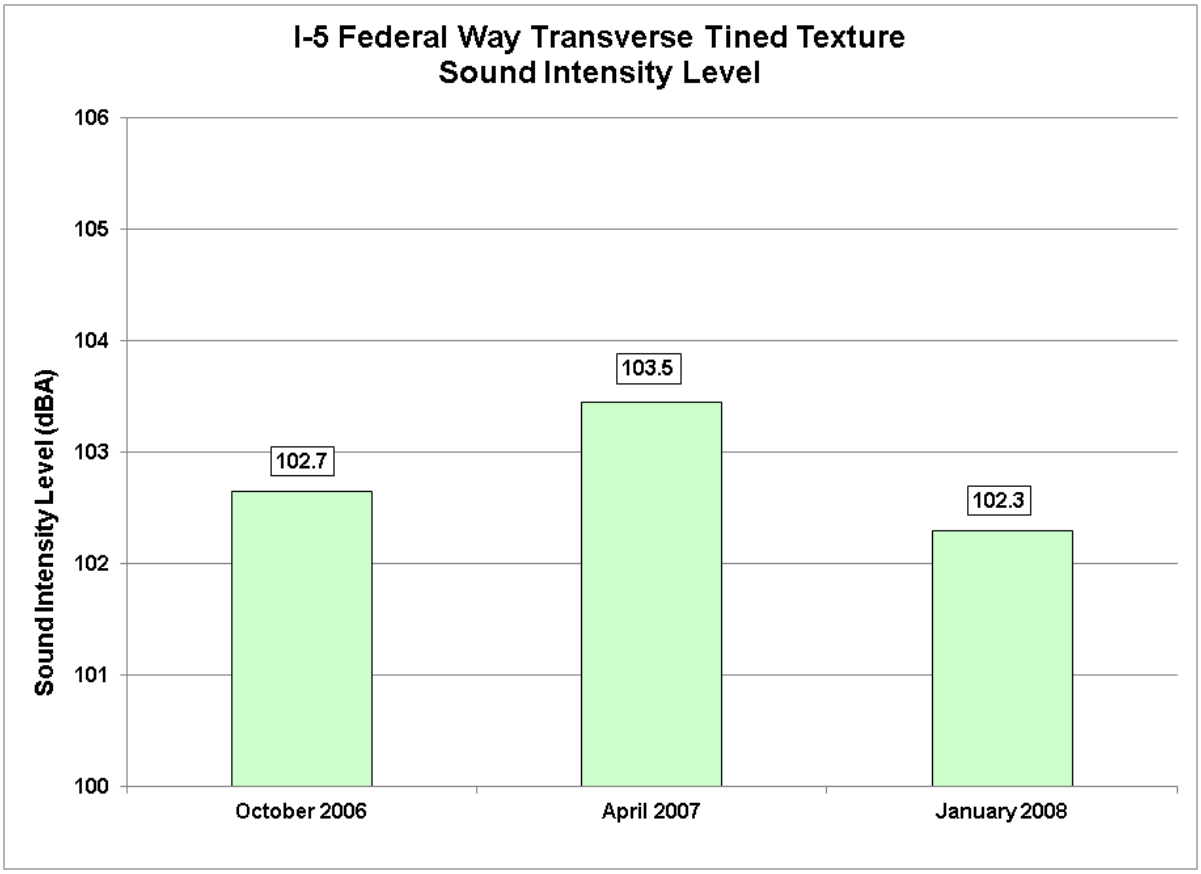


Figure 19. Sound intensity level data for transverse tined concrete on I-5 near Federal Way.

I-82 Sunnyside

A 1,500 foot section of Next Generation Concrete Surface was installed on I-82 near Sunnyside Washington in October of 2010. The NGCS section was located in both eastbound lanes in the middle of a dowel bar retrofit project that included diamond grinding of lanes adjacent to the NGCS section (Figure 20). The NGCS is constructed in a two step process; (1) grind a flat smooth surface, and (2) cut grooves 1/8 inch wide and 3/8 inch deep into the surface at 1/2 inch intervals parallel to the center line of the roadway (Figure 21). The noise levels of the conventional diamond grinding located west of the NGCS are also reported.

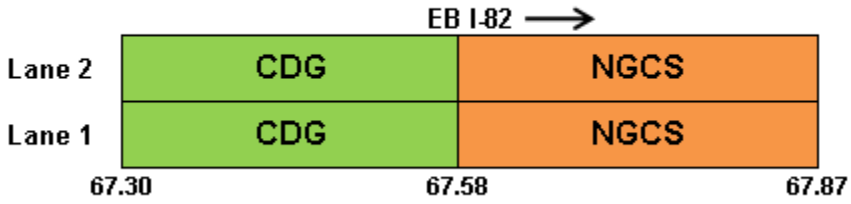


Figure 20. Test site on I-82 with NGCS and conventional diamond ground surfaces.

Next Generation Concrete Surface

Visual inspection of the NGCS noted a high number of missing aggregate from the edges of the grooves cut in the surface of the concrete (Figure 22). The noise reading gradually increased over a period of about 29 months from an initial value of 100.6 dBA in November of 2010 to a peak value of 105.9 dBA in April of 2012. In April of 2013, levels decreased to 104.4 (Figure 23). The average for the six reading was 103.7 dBA. The additional roughness resulting from the loss of aggregate from studded tire wear may account for the increase in noise levels noted.

Figure 21. I-82 NGCS October 2010 after construction.

Figure 22. I-82 NGCS May 2013.

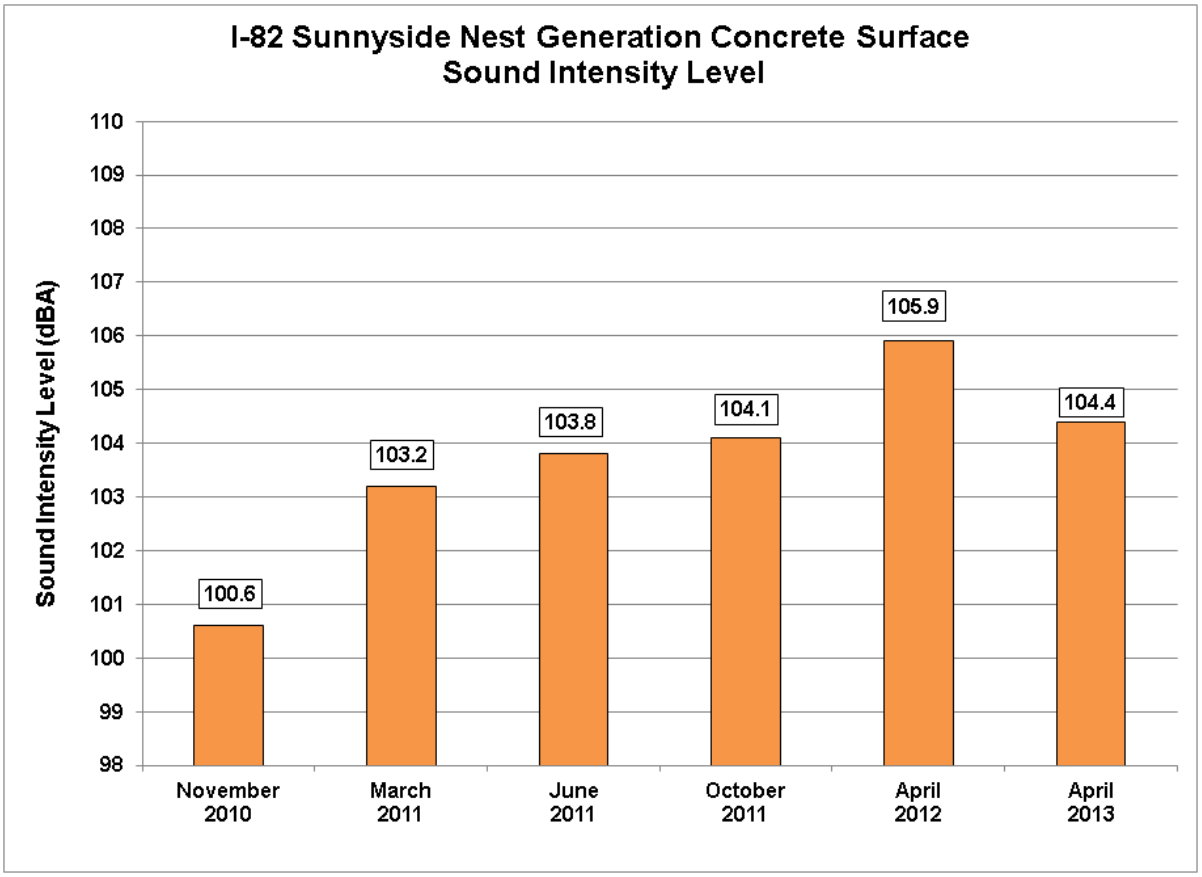


Figure 23. Sound intensity level data for NGCS on I-82 near Sunnyside. June 2011 readings courtesy of Larry Scofield, American Concrete Paving Association (ACPA) and International Grooving and Grinding Association (IGGA).

Conventional Diamond Grinding

The noise readings on the conventional diamond ground pavement ranged from an initial value of 103.7 dBA to a peak of 105.1 dBA in October 2011, then decreasing to 104.5 dBA in April of 2013 (Figure 24). The average for the six readings was 104.4 dBA.

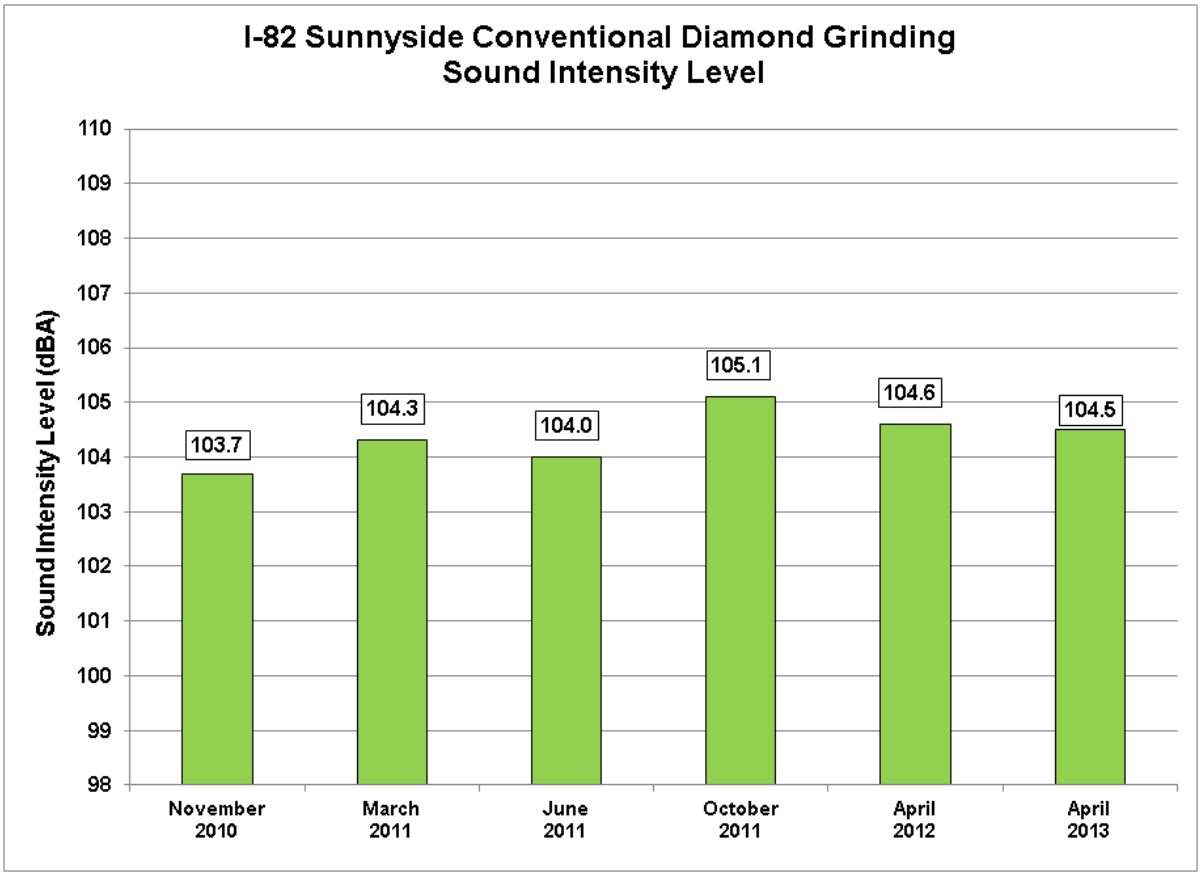


Figure 24. Sound intensity level data for conventional diamond ground concrete on I-82 near Sunnyside. June 2011 readings courtesy of Larry Scofield, American Concrete Paving Association and International Grooving and Grinding Association (see Reference section).

I-5 Northgate

The northbound and southbound lanes of I-5 between Boeing Field and King/Snohomish County Line were rehabilitated in 2009 under a project that replaced badly cracked panels and diamond grinding portions of all lanes. The end mileposts of the diamond ground sections are noted in Figure 25. It should be noted that many areas did not receive grinding. The noise measurements were taken in the outside lanes in each direction.

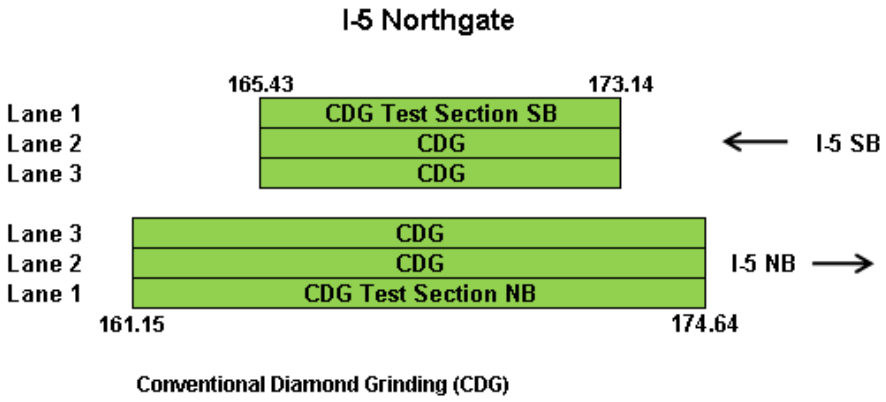


Figure 25. Diamond grinding on I-5 between Boeing Field and King/Snohomish County Line.

Conventional Diamond Grinding

Noise measurements made on the existing concrete pavement in March of 2009, prior to diamond grinding, revealed a very high reading of 108.2 dBA (Figure 26). The average value after construction showed a 3.5 dBA reduction at 104.7 dBA.

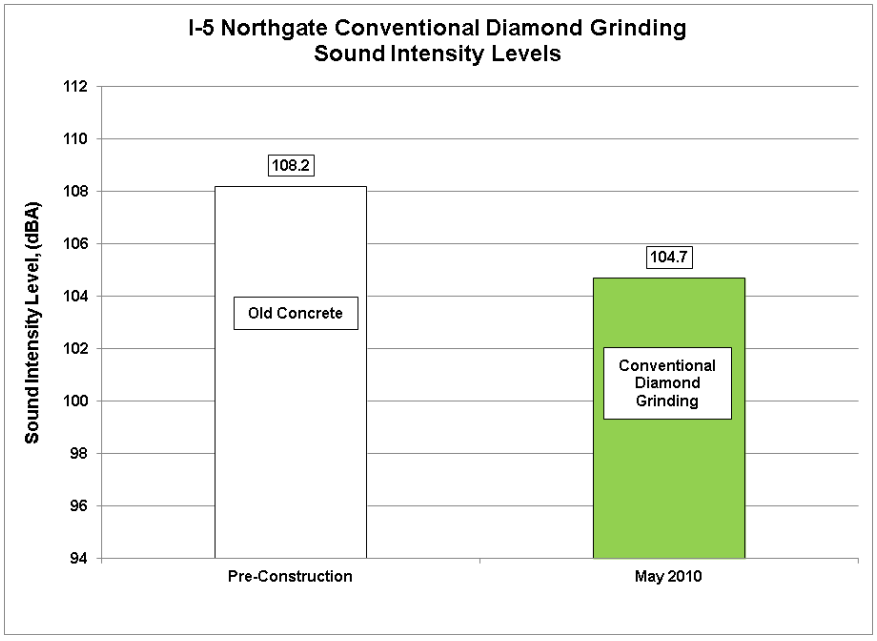


Figure 26. I-5 Northgate sound intensity level data for CDG.

Discussion of Results

Table 1 summarizes the initial and final sound intensity level readings for each of the finishing or texturing methods. Observations concerning the data are highlighted in the following bullets:

- The lack of variation and high noise levels for the transverse tined and carpet drag pavements on I-90 in Spokane suggest that the pavements are devoid of any texture except that caused by studded tire wear. This was confirmed by visual inspection.
- The decrease in noise levels over time for the two sections of longitudinal tined pavement on I-90 Easton and I-5 Federal Way would seem to indicate that traffic wear is having a positive effect on the noise levels by removing some of the as-built surface roughness. The result may be a texture that is somewhat similar to the NGCS with a smooth surface and longitudinal grooves.
- The mixed results from the two conventional diamond ground sections on I-90 Easton and I-82 Sunnyside do not lend themselves to a definitive explanation. The section on I-82 seems to indicate that the noise level is rather consistent and not changing rapidly. The noise level on the I-90 Easton section increased in gradual steps until the last reading.
- The carpet drag and transverse tined sections on I-5 Federal Way did not change a great deal over the thirteen month monitoring period. The absence of large changes in noise level may be the result of the lower amounts of traffic wear on median side HOV lanes.
- The NGCS produced the quietest noise level for any of the sections, but that level could not be maintained for any length of time. The rapid increase in the noise level from 100.6 to 103.2 dBA in only four months would seem to indicate that the NGCS is not a viable choice for quieter pavement in Washington. However, the reports of multiple missing aggregate cannot be discounted as a contributor to the increased noise levels. The NGCS has worked well in other locations across the United States, but these are locations not subject to studded tire traffic.

Table 1. Initial and current sound intensity levels for various concrete finishing and texturing methods.

Texture	Pavement Age at Initial Test (months)	Initial Sound Intensity Level (dBA)	Final Sound Intensity Level (dBA)	Sound Level Difference (dBA)	Time Between Initial and Final Reading (months)
Carpet Drag (I-90 Spokane)	72	106.1	107.4	+1.3	78
Carpet Drag (I-5 Federal Way)	16	102.2	103.0	+1.2	15
Transverse Tining (I-90 Spokane)	24	107.4	108.6	+1.2	78
Transverse Tining (I-5 Fed. Way)	3	102.7	102.3	- 0.4	15
Longitudinal Tining (I-90 Easton)	11	105.0	104.6	- 0.4	25
Longitudinal Tining (I-5 Fed. Way)	3	103.8	102.0	- 1.8	15
NGCS (I-82 Sunnyside)	1	100.6	104.4	+3.8	29
CDG (I-90 Easton)	11	105.4	103.7	-1.7	25
CDG (I-82 Sunnyside)	1	103.7	104.5	+0.8	29
CDG (I-5 Northgate)	9*	104.7	-	-	-

*** Estimated, exact date of completion of the grinding not known.**

Conclusion

Studded tire wear has a negative effect on the noise levels of concrete pavements on Washington highways. The data from the sections monitored in this study indicate that the noise levels will eventually rise to the 104 to 108 dBA range, regardless of the initial noise level following construction. The only exceptions noted in this study were the sections located on the lightly traveled HOV lanes on I-5 Federal Way.

References

Anderson, K., Uhlmeyer, J., Sexton, T., Russell, M., Weston, J. **Evaluation of Long-Term Performance and Noise Characteristics of Open-Graded Friction Courses – Project 1: Final Report**, Washington State Department of Transportation, WA-RD 683.2, June 2012.

Anderson, K., Uhlmeyer, J., Sexton, T., Russell, M., Weston, J. **Evaluation of Long-Term Pavement Performance and Noise Characteristics of Open-Graded Friction Courses – Project 2: Final Report.** Washington State Department of Transportation. WA-RD 691.2, June 2012.

Anderson, K., Uhlmeyer, J., Sexton, T., Russell, M., Weston, J. **Evaluation of the Long-Term Performance and Noise Characteristics of Open-Graded Friciton Courses – Project 3: Final Report.** Washington State Department of Transportation. WA-RD 749.2, July 2013.

Scofield, L. **2011 Washington NGCS OBSI Test Results – Preliminary Results,** International Grooving and Grinding Association, January 2012.