Evaluation of Long-Term Pavement Performance and Noise Characteristics of the Next Generation Concrete Surface

WA-RD 767.1

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April 2011

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WSDOT Research Report

Experimental Feature Report

Report
Experimental Feature WA 10-03

Evaluation of Long-Term Pavement Performance and Noise Characteristics of the Next Generation Concrete Surface

Contract 7885
I-82
Granger to W. Grandview EB – Dowel Bar Retrofit and Concrete Rehab
MP 57.85 to MP 72.58

Washington State Department of Transportation

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

16. ABSTRACT

This report documents the construction of the first Next Generation Concrete Surface (NGCS) by the Washington State Department of Transportation (WSDOT). A 1,500 foot test section was installed on the eastbound lanes of I-82 near Sunnyside, WA in October of 2010. Baseline measurements of noise, friction, wear and smoothness are reported. The sound intensity levels of 101.6 and 99.6 for the outside and inside lanes, respectively, are within the range reported for other NGCS projects.

A literature review is provided that documents the development of the NGCS process as well as descriptions and results from the initial field trials in the U.S.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
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DISCLAIMER

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

This report documents the construction and initial testing of a section of Next Generation Concrete Surface (NGCS) installed on I-82 near Sunnyside, Washington. Next Generation Concrete Surface is the term applied to a new method of diamond grinding that produces the quietest concrete pavement surface tested to date. This project is part of a continuing effort by WSDOT to test new methods of decreasing the noise generated from highway facilities. Noise can be decreased by changing the texture of new or existing concrete pavements or, in the case of asphalt pavements, by using special asphalt mixes. For concrete pavements, sections of different types of finishing methods have been incorporated into projects in both the Seattle and Spokane urban areas between 2004 and 2010. For asphalt pavements, test sections of open-graded friction course pavement were built on three high volume roadways in the Seattle urban area between 2006 and 2009. The subject of this report, the installation of NGCS on I-82, is the first section of NGCS installed by WSDOT. Table 1 summarizes the quieter asphalt projects and the projects that have used different concrete finishing methods to combat noise.

Table 1. Projects with quieter asphalt or concrete pavement features.

Construction Year	Project	Feature Installed
2004-2005	I-90, Spokane, Argonne Rd to Sullivan Rd	Carpet drag texture
2005	I-5, Federal Way, Federal Way to S. 317th Street HOV Direct Access	Carpet drag texture
2006	I-5, Federal Way, Pierce County Line to Tukwila I/C – HOV – Stage 4	Carpet drag texture, longitudinal tining
2006	I-5, Lynnwood, 52nd Avenue West to SR 526 - Southbound	Open graded friction course mixes with recycled rubber and polymer additives
2007	SR 520, Medina, Eastside Quieter Pavement Evaluation Project	
2009	I-405, Bellevue, 112th Avenue SE to SE 8th Street	
2009	I-90, Lake Easton Vic to Bullfrog Rd I/C Vic WB – Replace PCCP	Longitudinal tining, conventional diamond grinding (CDG)
2010	I-405 Bellevue Design Build	Longitudinal tining
2010	US 395 North South Connection in Spokane	Longitudinal tining

Literature Search

The NGCS was developed through the combined efforts of the American Concrete Paving Association (ACPA), the Portland Cement Association (PCA), and the International Grooving and Grinding Association (IGGA). This effort was initiated in response to the efforts by the asphalt paving industry and various state DOTs to produce quieter asphalt pavements. The research effort was split into two phases, a laboratory phase that investigated the noise generated from different diamond grinding textures, and a field trial phase with installations of the newly designed texture at various U.S. sites.

Laboratory Phase

The laboratory phase of the research was conducted at Purdue University's Herrick Laboratories beginning in 2005. The work investigated the variables that affected tire-pavement noise generation characteristics of diamond-ground surfaces (1). The Tire Pavement Test Apparatus (TPTA) was used to perform the laboratory testing. As seen in Figure 1, the TPTA consists of a revolving drum onto which slabs of concrete are attached. Tires run on the surface of the slabs as the drum rotates at speeds up to 30 mph. On-Board Sound Intensity (OBSI) measuring equipment is attached near the tire-pavement interface to measure the noise in the same manner as it is used to measure tire/pavement noise on highways. Twelve different surface textures can be tested at one time using the TPTA.

Figure 1. Tire Pavement Test Apparatus (TPTA) located at Purdue University's Herrick Laboratory. (Photo from Purdue University website)

Initial research efforts focused on measurement of the noise produced from slabs prepared using existing methods of diamond grinding. It was thought that different configurations of the blades and spacers were the key to producing a quieter surface. Findings, however, indicated that the configurations of the blades and spacers were not the controlling factor in the noise that was generated (1). The controlling factor was found to be the fin profile of the diamond-ground surface. A fin is a positive texture (sticks above the surface) as contrasted with a groove which is a negative texture. Uniform and consistent profiles with a minimum of positive texture were found to be the key to generating a low-noise surface. A new surface was then designed that consisted of a uniform profile with only negative texture. This produced the lowest laboratory noise test results. The new surface was named the Next Generation Concrete Surface. Figure 2 shows a positive fin texture and Figure 3 the NGCS texture with its uniform flat land surfaces and negative texture grooves.

Figure 2. Positive fin texture produced by conventional diamond grinding. (1)

Figure 3. NGCS on I-82 with flat land surfaces and negative grooves

Field Trial Phase

The field trial phase was used to verify the laboratory findings through the construction of test installations of the NGCS. Two methods were developed to produce the NGCS grinding pattern in the field, the single pass and the two pass method. The two pass method grinds the pavement smooth in one pass and then puts the grooves in on the second pass. The single pass method uses a blade configuration that grinds the pavement smooth and cuts the grooves in one pass. The two methods were developed to ensure that contractors would have the option of using the two pass method that might be easier on equipment if the pavement is very hard, or the more aggressive single pass method if conditions are such that the pavement is easier to grind (1).

The first field trial of the NGCS was at one of the test cells on MnROAD's Low Volume Road located west of Minneapolis in October of 2007. A grinding machine with a special head was used to cut an 18-inch wide strip the length of the test cell. Three strips were ground, one with the NGCS cut in a single pass, one with the NGCS cut using the double pass method and one with conventional diamond grinding (CDG). One strip was left as a control section with its existing random transverse tining. The results of OBSI testing immediately after the grinding was completed are shown in Table 2 (1).

Table 2. OBSI results from initial NGCS field trial at MnROAD Low Volume Road cell 37. (1)

Texture Type	10/25/07 (dBA)
NGCS Double Pass	99.1
NGCS Single Pass	99.4
CDG	102.0
Random Transverse Tining	103.0

The I-355 Veterans Memorial Tollway in Chicago was the site of the first full-lane-width installation of NGCS. In October of 2007 a section 1,200 feet in length was constructed using the two pass method along with a companion control section of CDG. The OBSI sound intensity data from post-construction through June of 2010 is shown in Table 3 (2). Note the consistency of the sound measurements across the three year span of time.

Table 3. Historical OBSI sound intensity readings from I-355 Veterans Memorial Tollway. (1)(2)					
Texture	Post Const. (dBA)	11/4/07 (dBA)	5/12/08 (dBA)	2009 (dBA)	6/19/10 (dBA)
NGCS	99.6	100.5	100.9	101.2	100.3
CDG	100.2	100.7	100.9	(1)	100.2

(1) Not tested.

The next full-lane-width NGCS was installed on MnROAD's mainline I-94 Cell 7 in October of 2007. A control section of CDG was installed on adjacent Cell 8. OBSI data for these cells shown in Table 4 includes follow up testing through June of 2010 (3). Note again the consistency of the measurements over time for the NGCS. The much higher reading for the CDG right after construction followed by lower readings over time may be due to the presence of positive texture fins that are worn away over time.

Table 4. Historical OBSI sound intensity readings for MnROAD's cell 7 and 8. (1)(3)					
Texture	Cell	10/25/07 (dBA)	5/12/08 (dBA)	7/07/09 (dBA)	6/18/10 (dBA)
NGCS	7	100.1	99.0	101.1	99.8
CDG	8	104.3	100.7	102.1	101.8

The next two projects constructed were in Wisconsin and Kansas. The Wisconsin NGCS was the first trial that was bid as a normal construction item and not as a change order or trial section constructed by the industry. Unfortunately, the Wisconsin project is on a low speed roadway through a small town making it impossible to safely test at 60 mph. The Kansas section on I-70 was part of a project that used the two-lift European technique for the construction of the concrete pavements. The two-lift technique uses lower quality aggregate in a thicker lower layer with a high quality aggregate in the thinner upper wearing layer. Seven test sections were constructed using various textures including a NGCS and CDS section as shown in Table 5 (4).

Table 5. Post-construction OBSI sound intensity readings on the Kansas two-lift concrete pavement. (4)			
Texture	**10/19/08 (dBA)**	**10/27/09 (dBA)**	**5/21/10 (dBA)**
NGCS	99.4	100.5	100.9
CDG	101.7	102.1	102.8
Longitudinal Grooved	101.2	101.8	101.9
Carpet Drag	101.3	--	102.6
Longitudinal Tined	--	102.9	103.1
Exposed Aggregate	103.2	104.5	104.5

Mn/DOT built the largest project to date with 104,000 square yards of NGCS installed on a section of I-35 through downtown Duluth, Minnesota in September of 2010. The existing surface was a 20-year old pavement on one end and a 45-year old pavement on the other end. The initial OBSI test results are summarized in Table 6 (5).

Table 6. OBSI results from I-35 in Duluth, MN. (5)		
Texture	**Direction**	**9/17/10 (dBA)**
NGCS	NB	100.5
NGCS	SB	100.2
Existing Pavement (transverse tined)		107.2

Concrete Pavement Noise Level Discussion

A summary of the range of OBSI noise readings from the various finishing and diamond ground textures is shown in Figure 4 (6). The noisiest concrete pavement texture is the transverse tining which has been required by FHWA for many years. The noise generated by this surface is typically in the 103 to 110 decibel range. Longitudinal tining, which many states including Washington are instituting as a replacement for transverse tining, is the next quietest texture at 101 to 106 decibels. Conventional diamond grinding is next quietest at 100 to 104 decibels, followed by the quietest, the NGCS at 99 to 101 decibels.

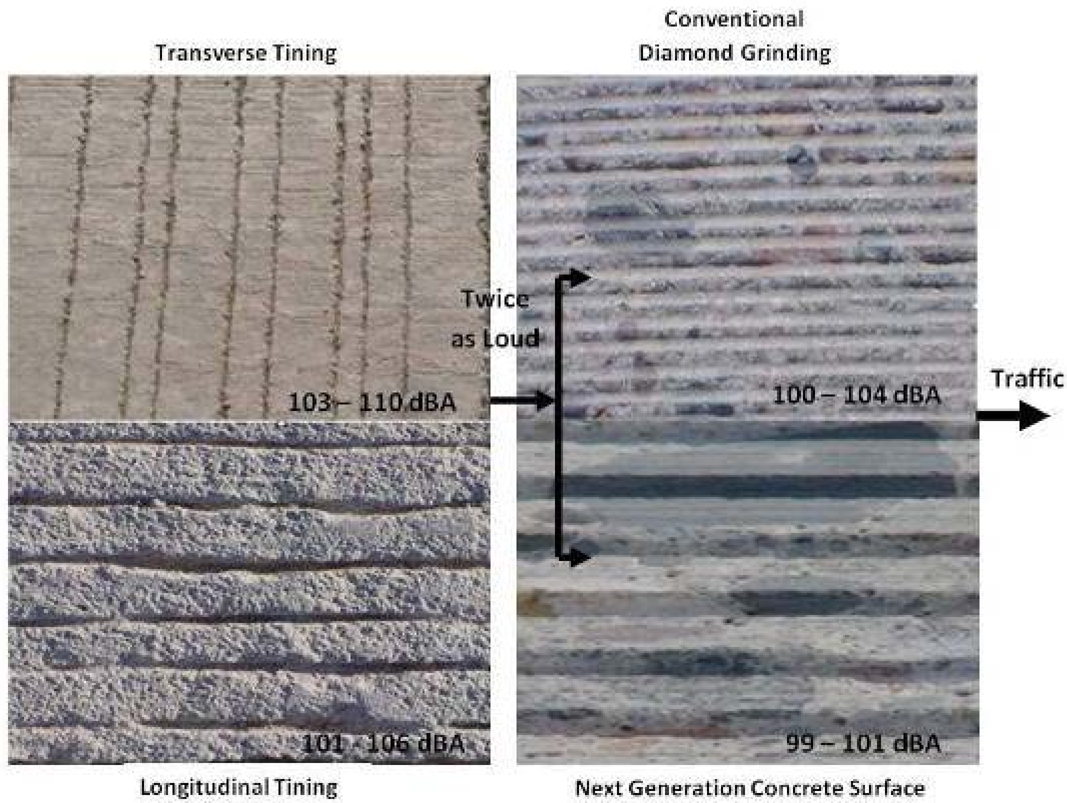

Figure 4. Two common concrete finishing textures, conventional diamond grinding and NGCS and their typical OBSI sound intensity readings. (6)

Table 7 shows sound level changes and how they affect loudness and acoustical energy. A three decibel difference is considered to be a perceptible change by most acoustical engineers; however, it is only changes greater than three decibels that are readily perceptible and a good difference to aim for with any noise mitigation strategy. The NGCS at 99-101 decibels would be a big improvement over transverse tining at 103-110 decibels with a minimum difference of four decibels at the low end and nine at the high end of their relative noise ranges. The difference provided by the NGCS might not be as perceptible versus a longitudinal tined texture except at the high end of the longitudinal tining range. A perceptible hearing difference between a NGCS and a conventional diamond ground surface may be even less likely.

Table 7. Sound level change, loudness and acoustic energy loss. (6)		
Sound Level Change	**Relative Loudness**	**Acoustic Energy Loss**
0 dBA	Reference	0
-3 dBA	Barely Perceptible Change	50%
-5 dBA	Readily Perceptible Change	67%
-10 dBA	Half as Loud	90%
-20 dBA	1/4 as Loud	99%
-30 dBA	1/8 as Loud	99.9%

Project Location

Dowel bar retrofit and panel replacement was the focus of Contract 7885 under which the trial section of NGCS was installed. The project map and the location of the NGCS and CDG sections are shown in Figures 5 and 6.

Figure 5. Project map of Contract 7885, Granger to W. Grandview – Dowel Bar Retrofit and Concrete Rehab.

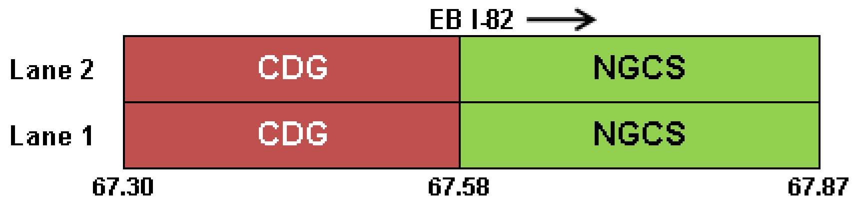

Figure 6. Plan map of the NGCS and CDG sections.

Construction

The dowel bar retrofit operations were conducted first followed by the diamond grinding to construct the NGCS. The contractor, Penhall Company, chose the two pass method due to the hardness of the aggregate in the pavement (see Appendix A). The first pass ground the pavement surface to a flush profile using a four foot grinding head stacked with 0.125 inch blades separated by 0.030 inch spacers (Figure 7). The second pass cut the longitudinal grooves using a grinding head with blades that were 0.125 inch wide and 0.125 inch to 0.375 inches deep. Spacers were used to separate the grooves 0.5 inches apart from center to center (Figure 8). The grooves were cut parallel to centerline. Observations and comments on the construction of the project as witnessed by Jim Weston, WSDOT Pavement Division, are documented in Appendix B.

Figure 7. Grinding head for the first pass flush grind operation.

Figure 8. Grinding head for cutting the grooves on the second pass.

Construction began on October 4, 2010 and was completed the following day. The entire roadway had been ground previously using conventional diamond grinding methods as part of the dowel bar retrofitting operation. This was done for two reasons, the first being to restore the surface of the pavement to remove faulting, and the second, to lessen the blade wear on the flush grinding head used for the first pass of the NGCS installation.

Once the conventional grinding was complete the first pass with the grinding machine fitted with the fine grinder head was positioned at the outer edge of the travel lane. Grinding progressed eastbound from MP 67.58 to the end of the trial section at MP 67.87, a distance of 1,500 feet. Multiple passes completed the fine grinding of the two lanes of the test section. Figures 9 and 10 compare the pavement surfaces after conventional diamond grinding and the first pass of the NGCS with the fine grinding head.

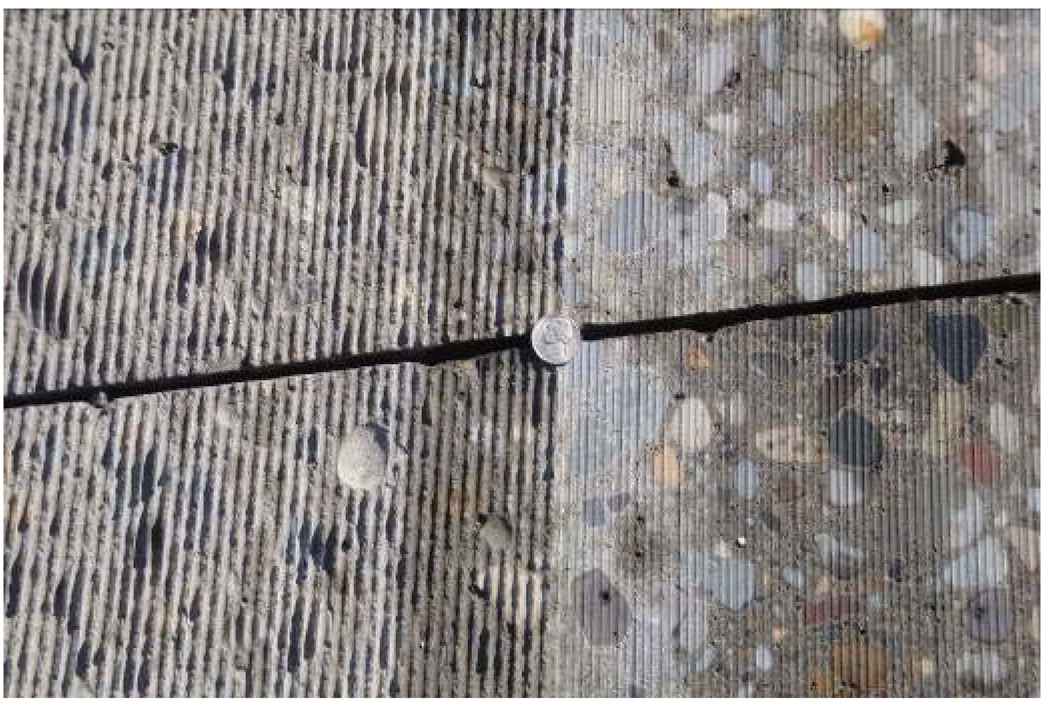

Figure 9. Conventional diamond ground surface on the left, fine flush grind surface of the NGCS first pass operation on the right.

Figure 10. Close-up of the CDG surface on the left and the, first pass of the NGCS on the right.

The second pass to groove the pavement was done with a second grinding machine. The machine was again positioned at the outside edge of the outside lane and progressed eastbound to the end of the test section making multiple passes to complete the two lanes. The final surface had flat, smooth land areas separated every 1/2 inch by 3/16 inch deep grooves as shown in Figures 11-13.

Figure 11. Conventional diamond ground surface on the left, first pass of NGCS in the middle and final pass of the NGCS on the right.

Figure 12. Finished surface of the NGCS with wide, flat land areas and deep grooves.

Figure 13. Close-up of NGCS with shoulder stripe in the foreground.

The contractor used three grinding machines on the project and reported no difficulties accomplishing the work of installing the NGCS. The project office indicated in January of 2011 that the State Patrol had received no complaints regarding the NGCS. Installation and operating characteristics of the NGCS seem to be in line with other such installations reported in the literature.

Construction Costs

Penhall Company, a member of the International Grinding and Grooving Association (IGGA) agreed to do the two lane wide 1,500 foot test section for $12.75 per square yard. The total price for the 4000 square yards on the project was $51,000. The average cost of conventional diamond grinding in various WSDOT Regions is captured in Table 8 to serve as a comparison of grinding costs incurred with the NGCS construction. As expected the cost of the

NGCS at $12.75 per square yard is highest, but given the small size of the project and the newness of the process, this was not unexpected.

Table 8. Conventional diamond grinding costs for dowel bar retrofit project in Washington from 2008 to 2010.

Location	Grinding Cost ($ per square yard)
Northwest Region	11.55
South Central Region	6.35
Southwest Region	10.34
Eastern Region	11.43
Statewide Average	**8.26**

Post-Construction Testing

OBSI noise testing of the new NGCS was done on November 8, 2010 following the construction in October. Friction measurements were made on November 3, 2010 at 40 mph using a ribbed tire. The results are summarized in Table 9. The friction numbers are very good for both the NGCS and CDG and what are expected of a newly ground surface.

Table 9. Post-construction friction and noise data.

Section	Lane	Friction (FN)	Noise (dBA)
NGCS	EB1	47.1	101.6
NGCS	EB2	50.8	99.6
CDG	EB1	56.2	104.4
CDG	EB2	52.8	103.0
Existing Pavement (transverse tined)			106.2

Note: NGCS is from MP 67.58 to 67.87; CDG is from MP 67.29 to 67.58

The noise measurements for the NGCS are in line with what has been reported in the literature (99-101 decibels) as are the values for the CDG (100-104 decibels). The existing pavement, a transverse tined concrete built in 1982, was tested in April of 2010 prior to any work on the project and the average for three sites was 106.2 decibels. The NGCS is 5-6 decibels quieter than the existing pavement and 3-4 decibels quieter than the CDG surface (Figure 11). The difference in noise levels between the NGCS and the existing pavement would be in the readily perceptible range, while the difference between the NGCS and CDG would be in the barely to readily perceptible range (see Table 7, page 15). The sound intensity level measurements for the old concrete, the NGCS and the CDG are compared in the Figure 12 bar chart.

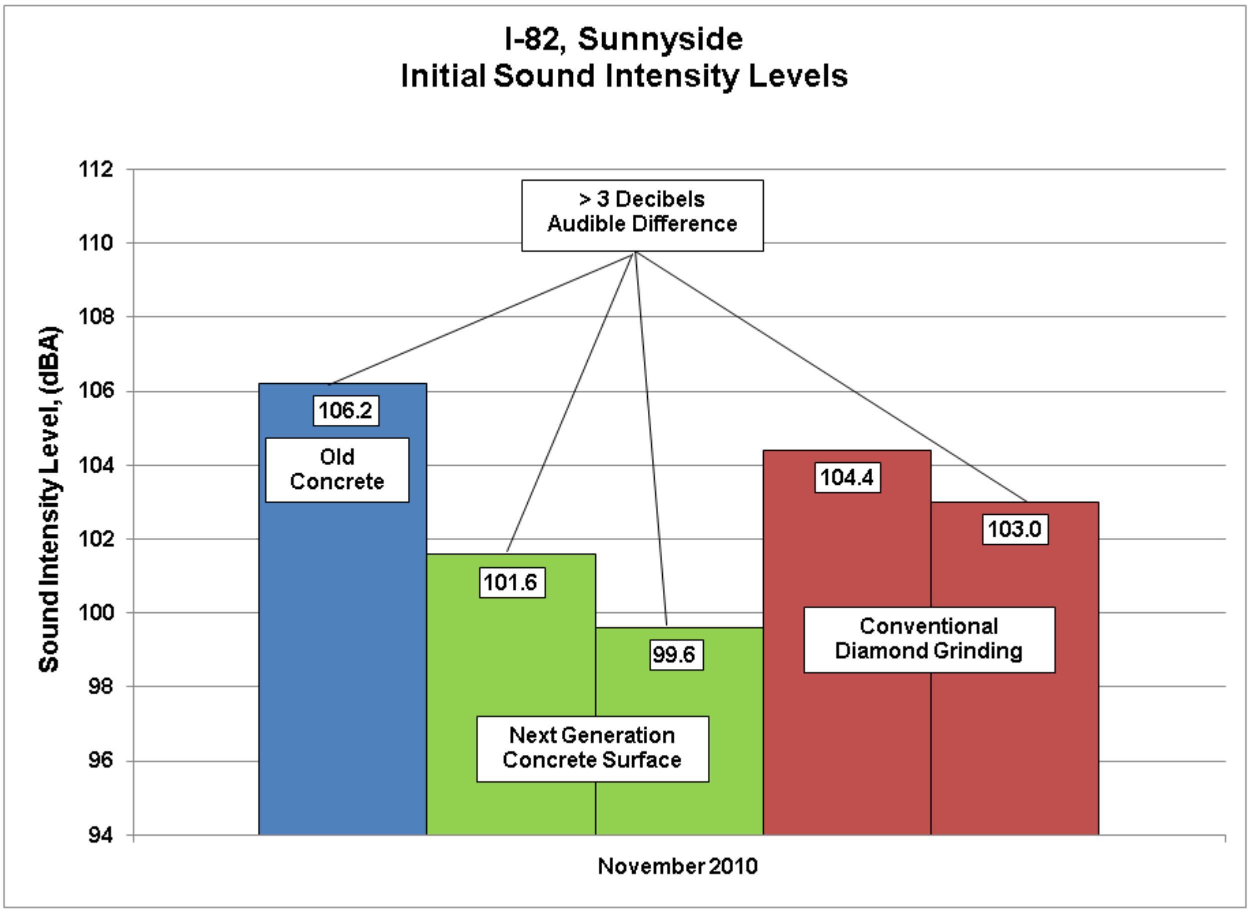

Figure 14. Initial sound intensity levels for the exiting concrete pavement, the new NGCS and CDG sections.

Future Research

The NGCS and CDG test sections will be monitored for a period of at least five years, and longer if results of the noise testing indicate a greater longevity of the noise reduction than the five years. Noise, wear, roughness, and friction data will be gathered twice a year with measurements made in April and October to bracket the legal studded tire season (see Appendix A, Work Plan). WSDOT does not currently have the pavement profiling technology (such as a Roline sensor) to accurately remove the effect of the grooves in the NGCS for roughness measurements.

Larry Scofield, America Concrete Paving Association, provided comments on the draft of this report and mentioned several areas of interest regarding the grooves in the NGCS as noted below:

- Does water or snow collect in the grooves and freeze during the winter?
- Does the NGCS section require more anti-icing chemicals because of the grooves?
- Does the presence of the grooves increase studded tire wear on the pavement?
- Are there any problems with lateral stability because of the grooves in the NGCS?

The first two questions will be answered by alerting our local Maintenance personnel to look for any differences in the way the NGCS section reacts to winter maintenance activities. Maintenance personnel reported no observable difference in maintenance requirements between the NGCS and the CDG for the 2010-11 winter season. Periodic photos of the change in texture over time in the exact same location may answer the third question. Finally, we will seek input from the state patrol, maintenance personnel, and perhaps local motorcycle clubs on any problems they have observed or experienced with vehicle instability on the test section.

References

1. Scofield, Larry (2010) “Development of Concrete Pavement Textures – Past and Present” paper presented at the 89th Annual TRB meeting January 10-14, 2010.

2. Scofield, Larry (2010) “Chicago I-355 Testing of NCHRP 10-67 Site Locations – Preliminary Report”, American Concrete Paving Association, June 2010.

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5. Scofield, Larry (2011) “Duluth I-35 Open House OBSI Testing”, American Concrete Paving Association, January 2011.

6. Scofield, Larry (2009) “Transportation Noise and Concrete Pavements – Using Concrete Pavements as the Noise Solution”, American Concrete Paving Association, May 2009.

Appendix A

Contract Change Order
(Retyped from the original)

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

DATE: 09/14/10

CHANGE ORDER

Page 1 of

CONTRACT NO: 007885 **FEDERAL AID NO:** ARRA-0822(132)
CONTRACT TITLE: I-82 GRANGER TO GRANVIEW CONCRETE REHAB
CHANGE ORDER NO: 7 CONSTRUCT NGCS TEXTURE SECTION

PRIME CONTRACTOR: 330349226 PENHALL COMPANY
14045 NORTHDALE BLVD

ROGERS MN 55375-9490

( ) Ordered by Engineer under the terms of Section 1-04.4 of the Standard Specifications

(X) Change proposed by Contractor

ENDORSED BY: **SURETY CONSENT:**

________________________ ____________________________________
CONTRACTOR Peter F. Lewis, Regional Manager **ATTORNEY IN FACT**
Penhall Company

9-30-2010
____________________ ____________________
DATE **DATE**

ORITINAL CONTRACT AMOUNT:	4, 798, 496.52
CURRENT CONTRACT AMOUNT:	4, 800, 536.52
ESTIMATED NET CHANGE THIS ORDER	51, 000.00
ESTIMATED CONTRACT TOTAL AFTER CHANGE:	4, 851, 536.52

Approval Required: **( ) Region** **( ) Olympia Service Center** **( ) Local Agency**

( ) APPROVAL RECOMMENDED **(X) EXECUTED** **EXECUTED:**

____ ___________________________________
PROJECT ENGINEER **STATE CONSTRUCTION ENGINEER**

10/7/10
___________________ ___________________
DATE **DATE**

( ) APPROVAL RECOMMENDED **( ) EXECUTED** **OTHER APPROVAL WHEN REQUIRED**

REGIONAL ADMIN:

____ ___________________________________
BY **SIGNATURE** **DATE**

____________________ ___________________
DATE **REPRESENTING**

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

DATE: 09/14/10

CHANGE ORDER

Page 2 of

CONTRACT NO: 007885 CHANGE ORDER NO: 7

All work, materials, and measurements to be in accordance with the provisions of the Standard Specifications and Special Provisions for the type of construction involved.

This contract is revised as follows:

Description
Section 5-01.1 is supplemented with the following:

(******)
This work shall consist of grinding concrete pavement to remove faulting, provide good riding characteristics and provide proper drainage.

Next Generation Concrete Surface Texture
This work also consists of constructing a test section of Next Generation Concrete Surface (NGCS) texture utilizing diamond grinding and grooving on an existing Portland cement concrete pavement.

Construction Requirements
Equipment
Section 5-01.3(1) B is supplemented as follows:
(******)
For the NGCS test section the Contractor shall use a diamond grinding machine with a 4 foot head.

Portland Cement Concrete Pavement Grinding
The first and second paragraphs of Section 5-01.3 (9) are revised to read as follows:

(******)
Once the grinding operation has started, it shall be continuous until completed. The pavement shall be ground in a longitudinal direction beginning and ending at lines normal to the pavement centerline. The maximum overlap between longitudinal passes shall be 1.50 inches. 95 percent of the surface area of the pavement is to be ground shall have a minimum of 1/8-inch removed by grinding.
Through roadway sections with a crown slope, the Contractor shall grind the lanes adjacent to the crown slope.
NGCS Texture
The construction of the NGCS test section can be accomplished as a single pass or two pass operation as determined by the Contractor. The existing pavement shall be pre-ground over the entire surface with a conventional diamond grinding process. The NGCS surface will be constructed after the pre-grinding has been completed.

The Contractor shall provide a single lane test grind of 500 feet in length to demonstrate that the equipment an procedures are capable of attaining the desired surface. The Contractor will not be allowed to proceed any further until the test grind has been approved in writing by the Engineer.
Single Pass Operation

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

DATE: 09/14/10

CHANGE ORDER **Page** 3 of

CONTRACT NO: 007885	CHANGE ORDER NO: 7

The construction operation will provide a flush ground surface that contains longitudinal grooves and shall be constructed in one single pass operation. The diamond blade stack shall consist of two types of diamond grinding blades arranged to provide a flush ground surface as well as those required to produce the longitudinal grooves. The diamond blade stack shall be mounted on a 4ft grinding head, stacked with 0.125 blades separated by spacers of 0.30 inches. The blades used to produce the flush grind surface should be flat across with other flush grind blades (excluding grooving blades) when mounted. The complete head when stacked with all blades shall be straight across its length without bowing when mounted on the diamond grinding machine. The flush grind blades shall be stacked in a manner that leaves no resulting fin between them. The grinding shall eliminate joint or crack faults and provide lateral drainage by maintaining a constant cross slope between grinding passes in each lane. The cross slope of the pavement shall match the existing and shall have no depressions or misalignment of slope greater than 0.125 inches in 10 feet when measured with a 10-foot straightedge placed perpendicular to the centerline. Areas of deviation shall be reground. Straightedge requirements will not apply across longitudinal joints or outside the ground area. Grinding shall begin and end at lines normal to the pavement centerline at the project limits. The blades used to create the longitudinal grooves shall be enough larger in diameter than the grinding blades used to create the flush ground surface so as to provide a groove depth of 0.125 to 0.375 inches. The longitudinal grooves shall be spaced among the flush grind blade stack approximately 0.5 inches center to center. The grooves shall be constructed parallel to the centerline. The Contractor shall us a guide to ensure proper alignment of the grooves to centerline.

Two Pass Operation
This construction method will allow for two separate operations to construct the NGCS section. The first operation will create the flush ground surface. The flush grind blades shall be mounted on a 4 foot grinding head, stacked with 0.125 blades separated by spacers of 0.030 inches. The flush grind head shall be flat across the blades when mounted on the diamond grinding machine with no bowing of the head. The flush grind blades shall be stacked in a manner that leaves no resulting fin between them. The grinding shall eliminate joint or crack faults and provide lateral drainage by maintaining a constant cross slope between grinding extremities in each lane. The cross slope of the pavement shall match the existing and shall have no depressions or misalignment of slope greater than 0.125 inches in 10 feet when measured with a 10-foot straightedge placed perpendicular to the centerline. Area of deviation shall be reground. Straightedge requirements will not apply across longitudinal joints or outside the ground area. Grinding shall begin and end at lines normal to the pavement centerline at the project limits. The second operation will provide the longitudinal grooves. The longitudinal grooves shall be 0.125 inches wide and will be 0.125 to 0.375 inches in depth.
The longitudinal grooves shall be spaced approximately 0.5 inches center to center. The grooves shall be constructed parallel to centerline. The Contractor shall use a guide to ensure proper alignment of the groves to centerline.

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

DATE: 09/14/10

CHANGE ORDER **Page** 4 of

CONTRACT NO: 007885	CHANGE ORDER NO: 7

Surface Finish
Section 5.01.3(9)A supplemented with the following:

(******)
NGCS Texture
The NGCS grinding process shall produce a pavement surface that is true to grade and uniform in appearance with a longitudinal grooved texture. The flush ground surface shall appear smooth and shall contain no ridges that exceed 0.03 inches. The longitudinal grooves shall be constructed parallel to centerline. At a minimum, 98% of the pavement surface shall be textured utilizing the NGCS. Depress pavement areas due to subsidence, edge slump or other localized causes will be excluded from this requirement when approved by the Engineer.
Measurement
Section 5-01.4 is supplemented with the following:

(******)
Next Generation Concrete Surface will be measured by the square yard final textured surface area regardless of the number of passes required to achieve acceptable results. Minor area of un-textured pavement within the designated areas to be textured will be included in the measurement.

Payment
The new bid item under Section 5-01.5 is revised to read as follows:

(******)
"Co #7 Construct NGCS Texture Section", per SQ YD
The unit Contract price per square yard shall be full compensation for all labor, equipment and material costs to complete the work as specified, including, removal and disposal of the residue from the grinding operations, and for all incidentals required.
The Contractor may disperse residue onto unpaved shoulders, adjacent roadside embankments, or median ditch areas of divided highways where the residue runoff can percolate into the soil, unless specified otherwise in the Contract.

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

DATE: 09/14/10

CHANGE ORDER

Page 5 of

CONTRACT NO: 007885 CHANGE ORDER NO: 7

ITEM NO	GROUP NO	STD ITEM		UNIT MEASURE	UNIT PRICE	EST QTY CHANGE	EST AMT CHANGE
39	01		CONSTRUCT NGCS TEXTURE SECTION	S.Y.	12.75	4,000.00	51,000.00
							51,000.00

Appendix B

Construction Comments and Observations

Next Generation Concrete Surface (NGCS)

Construction Comments

Interstate 82

Contract 7885, Granger to Grandview EB Dowel Bar Retrofit and Concrete Rehab

Milepost 57.85 to Milepost 72.58

The content of this report reflect the views of the author, Jim Weston, who is responsible for the facts and the accuracy of the data presented herein. The content does not reflect necessarily the official views or policies of the Washington State Department of Transportation.

INTRODUCTION

Portland cement concrete pavements (PCCP) are damaged less than HMA by studded tires, but typically generate more tire pavement noise than HMA pavements. A new method of diamond grinding has been developed called the “next generation concrete surface” (NGCS) that promises a surface texture that is considerably quieter than conventionally diamond ground surfaces. This new method was placed so it could be evaluated for constructability, durability over time, performance when wet or ice covered, noise and cost.

The NGCS can be constructed using either a single pass or two pass method with a pavement grinder. The single pass method utilizes three smaller blades stacked between two taller blades. This pattern is repeated across the grinding head and is known as a single pass system. The second method utilizes two grinding machines. The first machine is equipped with the smaller blades across the entire grinding head and flush grinds the pavement in one pass. The second grinder is equipped with the taller blades and spacers across the grinding head and grinds the grooves into the surface in the second pass.

PLAN OF STUDY

The primary focus of the study is to measure the noise reduction characteristics of the NGCS as compared to pavement that has not been resurfaced and pavement resurfaced with conventional grinding methods. In addition, the diamond ground surface’s resistance to studded tire wear, its durability, its friction resistance, and its splash/spray characteristics will also be evaluated as a part of the effort.

BACKGROUND

Panel replacement and dowel bar retrofitting was completed prior to the construction of the NGCS. The conventional diamond grinding of the PCCP surface required for dowel bar retrofitting had also been accomplished prior to the construction of the NGCS. The final step was the construction of the 1,500 test section of NGCS. This was done in both lanes beginning at MP 67.59 and progressing in the eastbound direction to MP 67.87.

TWO-PASS OPERATION

For this particular project, the two pass system was used. The two-pass operation has particular requirements for the grinding head and specifically the spacing of the blades. The following information is paraphrased from the Penhall Company's submittal for installation of the NGCS.

The construction method has two separate operations. The first operation creates the flush ground surface. The flush grind blades are mounted on a 4 ft. grinding head, stacked with 0.125 blades separated by 0.030 spacers. The flush grind head is flat across the blades when mounted on the diamond grinding machine with no bowing of the head allowed. The grinding eliminates the joint or crack faults and provides lateral drainage by maintaining a constant cross slope between grinding extremities in each lane. The cross slope of the pavement is to be constructed should not have depressions or misalignment of slope greater than 0.125 inch in 10 feet, when measured with a 10 foot straightedge placed perpendicular to the centerline. Any areas where deviations occur are to be reground. Straightedge requirements do not apply across the longitudinal joints or outside the area which is ground. Grinding is to begin and end at lines normal to the pavement centerline at the project limits. No un-ground surface area between passes is permitted.

The second operation provides the longitudinal grooves. The longitudinal grooves are to be 0.125 inches wide and 0.125 inches to 0.375 inches deep. The longitudinal grooves are spaced approximately 0.5 inches center to center. The grooves are constructed parallel to the centerline. The contractor will ensure proper alignment of the grooves to centerline by using a guide.

CONSTRUCTION

Construction of the NGCS began on October 4, 2010 and was completed the following day. Prior to placing the NGCS, the roadway surface was diamond ground using conventional surface grinding equipment. This was done for two reasons. The first reason is that the roadway surface needed to have the surface restored because faulting was present. The second reason is that the fine grinding head of the NGCS would encounter excessive blade wear if used to restore the pavement surface. This is also the reason for not utilizing the single pass NGCS system. Figure 15 shows the roadway surface after conventional grinding was completed.

Figure 15. Roadway surface after conventional grinding.

Once conventional grinding was complete the two pass NGCS began. The grinder outfitted with the fine grinding head was positioned in the outside portion of the outside lane (Lane 1) and progressed eastbound on I-82. When the fine grinding advanced down the roadway, the appearance of the surface was substantially smoother with grooves present. Figure 16 shows the fine grinding head and the configuration of the diamond blades and Figure 17 shows the pavement surface after fine grinding.

Figure 16. Configuration of fine grinding head and diamond blades.

Figure 17. Pavement surface after fine grinding.

When the fine grinding was complete, the grinder equipped with the taller blades commenced operation. The taller blade grind was also placed in the outside portion of the outside lane following the fine grinding machine. This is done to ensure that the taller blades achieve the required depth. Figure 18 shows the configuration of the taller diamond blades across the grinding head and Figure 19 shows the pavement surface after grinding with the taller blades.

Figure 18. Configuration of taller diamond blades.

Figure 19. Pavement surface after tall blade grinding.

The overall operation was no different than conventional grinding seen on dowel bar retrofit projects. The same equipment is used with the only variance being that different grinding heads were used to create a substantially diverse surface texture than typically seen. Figure 20 shows the conventional diamond grind texture next to the flush grind of the NGCS done prior to the cutting of the grooves. Figure 21 shows all three textures, the CDG, the flush grind, and the completed NGCS.

Figure 20. Conventional diamond grind on left with fine grind of NGCS on right before grooves were cut.

Figure 21. Conventional grind on left, fine grind in middle, and tall grind (complete NGCS) on right.

SUMMARY

- Conventional diamond grinding was complete prior to NGCS
- NGCS utilized the two pass grinding technique
  - Fine grinding followed the conventional grinding operation to smooth the land areas
  - Tall grinding followed the fine grinding operation to cut the grooves.
- The configuration of the blades and spacers on the grinding head were the only differences from conventional diamond grinding operations.

Appendix C

Experimental Feature Work Plan

Washington State Department of Transportation

WORK PLAN

EVALUATION OF LONG-TERM PAVEMENT PERFORMANCE AND NOISE CHARACTERISTICS OF THE NEXT GENERATION CONCRETE SURFACE

I-82

Granger to W Grandview EB – Dowel Bar Retrofit and Concrete Rehab

MP 57.85 to MP 72.58

Mark A. Russell, PE
State Pavement Design Engineer
Washington State Department of Transportation

Introduction

Portland cement concrete pavements (PCCP) are damaged less than HMA by studded tires, but typically generate more tire pavement noise than HMA pavements. A new method of diamond grinding has been developed called the “next generation concrete surface” (NGCS) that promises a surface texture that is considerably quieter than conventionally diamond ground surfaces. This new method needs to be evaluated for constructability, durability over time, performance when wet or ice covered, noise and cost.

Plan of Study

The objective of this research study will be to determine the long-term pavement performance characteristics of the NGCS method of diamond grinding. It will focus primarily on the diamond ground surface’s resistance to studded tire wear, its durability, its friction resistance, and its splash/spray characteristics. In addition, noise reduction characteristics will also be a part of the evaluation effort. WSDOT, at a minimum, will be evaluating noise levels using on-board sound intensity measurement equipment to capture tire/pavement noise.

Scope

This project will construct a 2,000 foot test section of NGCS in both eastbound lanes of I-82 located between mileposts 60 and 70.

Layout

The exact location of the test section will be layed out in the field prior to construction.

Staffing

This research project will be conducted through the combined efforts of the WSDOT Materials Laboratory and the WSDOT Acoustics Program Office. The South Central Region Project office will coordinate and manage all aspects of the construction. Representatives from the WSDOT Materials Laboratory (one – three persons) will also be involved in monitoring the construction activities.

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Testing

The following testing procedures will be conducted on the test sections and control section.

- Surface condition - both lanes (annually)
- Rutting/wear (biannually)
- Roughness (biannually)
- Friction (biannually)
- Sound intensity noise measurements (quarterly)

Reporting

An “End of Construction” report will be written following completion of the test sections. This report will include details of the construction of the test section and control section, construction test results, and initial sound, friction, roughness and rutting/wear results from all of the test sections. Annual summary reports will also be issued over the next five years that document any changes in the performance of the test sections. A final report will be written at the end of the five year evaluation period which summarizes performance characteristics and future recommendations for use of the next generation concrete surface grinding method.

Construction Costs

Construction costs are unknown at the time of the development of this work plan and no current cost data is available for the next generation concrete surface grinding method. Based on past cost data for grinding cement concrete pavement it is estimated the cost will be $21.00 per square yard. Based on an estimated quantity of 5,300 square yards the cost will be $111,300.

Testing Costs

Funds for all testing will come from the Quieter Pavements testing budget.

Report Writing Costs

Initial Report – 40 hours = $4,200
Annual Report – 10 hours (4 hours each) = $1,050
Final Report – 70 hours = $7,350

TOTAL EVALUATION COST = $12,600

Schedule

Estimated Construction – August/September 2010

Date	Pavement Condition Survey	Roughness Wear / Rutting	Friction	In-Vehicle Noise	Post Construction Report	Annual Report	Final Report
Summer 2010		X	X	X			
October 2010		X		X	X		
April 2011	X	X	X	X			
October 2011		X		X		X	
April 2012	X	X	X	X			
October 2012		X		X		X	
April 2013	X	X	X	X			
October 2013		X		X		X	
April 2014	X	X	X	X			
October 2014		X		X		X	
April 2015	X	X	X	X			
October 2015		X		X			
December 2015							X

Sound intensity will be tested quarterly.

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