# Virginia Quiet Pavement Implementation Program

## Second Interim Report

## HB 2040
## (2013)

**Report to the Governor and General Assembly of Virginia**

Virginia Department of Transportation
1401 East Broad Street
Richmond, Virginia 23219

**June 2013**

COMMONWEALTH of VIRGINIA

DEPARTMENT OF TRANSPORTATION
1401 EAST BROAD STREET
RICHMOND, VIRGINIA 23219 2000

Gregory A. Whirley
Commissioner

July 1, 2013

The Honorable Robert F. McDonnell
Members of the General Assembly

Dear Ladies and Gentlemen:

Chapter 790 of the 2011 Acts of Assembly (codified as Va. Code §33.1-223.2:21) directs the Virginia Department of Transportation (VDOT) to expedite the development of quiet pavement technology such that applicable contract solicitations for paving shall include specifications for quiet pavement and other sound mitigation alternatives in any case in which sound mitigations are a consideration. The legislation requires VDOT to construct demonstration projects sufficient in number and scope to assess applicable technologies. The assessment shall include evaluation of functionality and public safety of these technologies in Virginia's climate and shall be evaluated over two full winters. VDOT is also directed to provide interim and final reports that include results of the demonstration projects, results of the use of quiet pavements in other states, a plan for routine implementation of quiet pavement, and any safety, cost or performance issues that have been identified by the demonstration projects.

Chapter 120 of the 2013 Acts of Assembly amended Va. Code § 33.1-223.2:21 to provide for a second interim report and a 2-year extension of the deadline for the final report to June 30, 2015. The attached document is the second interim report. It provides the status of the lower noise pavement technologies that were demonstrated during the 2011 construction season. It also describes two additional demonstration projects that were constructed on Virginia highways in 2012 as well as two sections of quiet asphalt materials that were installed at the accelerated pavement testing facility at the National Center for Asphalt Technology (NCAT) at Auburn University in Auburn, Alabama. VDOT will continue its assessment of these demonstration projects throughout the next two years and will provide a final report regarding use of, and an implementation plan for, quiet pavement technologies by June 30, 2015, in accord with Va. Code §33.1-223.2:21.

If you have any questions or need additional information, please contact me.

Sincerely,

Gregory A. Whirley, Sr. FOR

Attachment

cc: The Honorable Sean T. Connaughton

# THE VIRGINIA QUIET PAVEMENT IMPLEMENTATION PROGRAM
# UNDER SECTION 33.1-223.2:21 OF THE *CODE OF VIRGINIA*
# SECOND INTERIM REPORT

Virginia Center for Transportation Innovation and Research
June 2013

## PREFACE

This study is being conducted under the direction of the Virginia Department of Transportation (VDOT) Materials Division with guidance from the Quiet Pavement Task Force (QPTF). The QPTF includes representatives from VDOT's Materials Division, Maintenance Division, and Environmental Division; the Virginia Center for Transportation Innovation and Research (VCTIR); the Virginia Asphalt Association (VAA); the American Concrete Paving Association (ACPA); the Virginia asphalt contracting industry; and the Virginia General Assembly. The QPTF includes the following individuals:

Mr. Charles A. Babish, P.E., State Materials Engineer, VDOT
Mr. Richard J. Schreck, Executive Vice President, VAA
Mr. Emmett R. Heltzel, P.E., Administrator, VDOT Maintenance Division
M. Trenton M. Clark, P.E., Director of Engineering, VAA
Mr. David T. Lee, P.E., Materials Engineer, VDOT Salem District, and Chair, VCTIR Asphalt Research Advisory Committee
Mr. Paul M. Kohler, Manager, VDOT Noise Abatement Section
Mr. Michael M. Sprinkel, P.E., Associate Director of Research, VCTIR
Mr. Kevin K. McGhee, P.E., Associate Principal Research Scientist, VCTIR
Mr. Edward C. Dalrymple, Jr., Vice President, Chemung Contracting Corporation
Mr. David M. Helmick, Vice President, Superior Paving Corp.
Mr. Robert R. Long, Executive Director, American Concrete Pavement Association
Del. James M. Lemunyon, Joint Commission on Transportation Accountability and Subcommittee on Quiet Pavements

This report was authored by Mr. Kevin K. McGhee, P.E. All tire-pavement noise and friction testing in the past year was conducted by researchers at the Virginia Tech Transportation Institute (VTTI). Most field evaluation activities were carried out by Mr. Daniel S. Mogrovejo, Graduate Research Assistant, and Mr. William K. Hobbs, Engineering Technician, of VTTI.

This is the second in a series of interim reports that chronicle the selection of lower-noise pavement technologies; the development and construction of demonstration projects; and the evaluation tools and analysis being used to compare the performance of the alternative strategies. This report focuses on the additional "quiet" pavement (QP) sections that were constructed in 2012, and it provides the performance status of the 2011 series of demonstration projects. As of spring 2013, the difference in measured tire-pavement noise between the control surfaces and the most successful (lowest noise) quiet asphalt technology was *readily noticeable* (≥5 dB). The lowest noise concrete surface continued to have a *readily noticeable* (~5dB) advantage over the standard concrete finish. Since they were first installed, there appears to have been a slight decrease in the noise of the quiet concrete surfaces and a slight increase in the noise of the quiet asphalt materials. In neither case is the difference perceptible to human hearing. All of the surfaces continue to have good resistance to skidding. Further, there have also been no reports of unique safety concerns associated with winter weather, and local maintenance crews have been proactive when addressing freezing precipitation on the porous surfaces.

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# EXECUTIVE SUMMARY

## Introduction

Chapter 790 of the 2011 Virginia Acts of Assembly (*Code of Virginia* § 33.1-223.2:21; see Appendix A) provides, in part:

> The [Virginia Department of Transportation] shall expedite the development of quiet pavement technology such that applicable contract solicitations for paving shall include specifications for quiet pavement technology and other sound mitigation alternatives in any case in which sound mitigation is a consideration. To that end, the Department shall construct demonstration projects sufficient in number and scope to assess applicable technologies. The assessment shall include evaluation of the functionality and public safety of these technologies in Virginia's climate and shall be evaluated over two full winters. The Department shall provide an interim report to the Governor and the General Assembly by June 30, 2012, and a final report by June 30, 2013. The report shall include results of demonstration projects in Virginia, results of the use of quiet pavement in other states, a plan for routine implementation of quiet pavement, and any safety, cost, or performance issues that have been identified by the demonstration projects.

Chapter 120 of the 2013 Acts of Assembly (see Appendix B) amended the foregoing language to provide for a second interim report and a 2-year extension of the deadline for the final report. This document is the second interim report. It provides the status of the lower noise pavement technologies that were demonstrated during the 2011 construction season. It also describes two additional trials that were constructed in 2012 and discusses two sections of quiet asphalt materials that were installed at the accelerated pavement testing facility at the National Center for Asphalt Technology (NCAT) at Auburn University in Auburn, Alabama.

## Background

### First Interim Report: June 2012

The first interim report was delivered to the General Assembly in June 2012. It described the selection of lower-noise pavement technologies (i.e., "quiet" pavement [QP]); the development and construction of demonstration projects for the first season (2011) of the project; and the evaluation tools and analysis that were used to compare the performance of the alternative technologies. The selected QP technologies included three asphalt surface materials and two mechanically applied finishes for concrete pavement. The three *asphalt* surface materials included two open-graded asphalt concrete mixtures (with different gradations) that used a polymer-modified binder. The third had a similar aggregate gradation but had a rubber-modified binder. The two *concrete* technologies were conventional diamond grinding (CDG) and the Next Generation Concrete Surface (NGCS), which consists of diamond grinding followed by a "flush-grind" operation and then a final longitudinal grooving step.

## 2012 Activity

Summer and fall 2012 activities included installation of two trial sections of quiet asphalt materials at the NCAT Pavement Test Track (www.pavetrack.com). The raw materials from the most promising 2011 demonstration technologies were sent to NCAT, blended with standard materials to produce "Virginia" QP technologies, and placed on the test track. Components of these technologies were also brought together to create two more demonstration projects in Virginia, one in the Northern Virginia District and the other in the Culpeper District.

# Purpose and Scope

This report is the second in a series of documents that chronicle the selection of lower-noise pavement technologies; the development and construction of demonstration projects; and the evaluation tools and analysis being used to compare performance of the alternative technologies. This second interim report is focused on the additional QP sections that were constructed in 2012 and also provides the status regarding the performance of the 2011 series of demonstration projects.

# Methods

## Selection of Technologies for 2012 Demonstration

Early feedback from the 2011 QP demonstrations helped researchers identify candidate technologies for additional pilot projects for the 2012 construction season. These preliminary findings were also instrumental in the selection of the technologies being subjected to accelerated trafficking at NCAT. Since none of the materials and treatments from 2011 had premature material failures or essential functional problems (such as low winter skid resistance), tire-pavement noise performance served as the key discriminator for determining which technologies to pursue

## Functional Evaluation

Evaluation of the original (2011) demonstration projects, as well as the assessment of the new 2012 projects, continues to focus on tire-pavement noise performance. Secondary testing to assess comfort and safety characteristics is also part of the regular regimen of tests. A complete description of each test method is included in the first interim report, but the current report does include a brief overview of the On-Board Sound Intensity (OBSI) and the GripTester continuous friction test methods for measuring noise and skid resistance, respectively.

# Preliminary Findings and Discussion

When comparing noise levels of QP technologies, it is important to understand that decibels (dB) are logarithmic units and cannot be added by normal arithmetic means. Although precision instruments can measure small changes in sound level, the human ear requires about

3 dB of difference for the change to be "noticeable." A 5 dB change is considered "readily noticeable" to most people, and a 10 dB difference is equivalent to a doubling (or halving) of the sound level.

As of spring 2013, the difference in measured tire-pavement noise between the control (typical) surfaces and the most successful (lowest noise) quiet asphalt technology was *readily noticeable* (≥5 dB). The lowest noise experimental concrete surface also maintained a *readily noticeable* (≥5 dB) advantage over the standard concrete pavement surface. The noise of the quiet concrete surfaces appears to have slightly decreased since the surfaces were first installed, whereas that of the quiet asphalt materials has slightly increased. In neither case is the difference perceptible by human hearing. All of the surfaces continue to have good resistance to skidding. There have been no reports of unique safety concerns associated with winter weather, and local maintenance crews are learning to be proactive (early and more frequent treatment) with regard to freezing precipitation on the porous surfaces.

### Costs and Quantities

Table ES1 shows the average initial cost and total quantity for each QP technology evaluated since the beginning of the program. Since the asphalt technologies are placed at varying thicknesses and the concrete technologies simply "refinish" the existing surface, the cost figures are normalized to an average per-surface-area cost (i.e., per square yard). Bear in mind that these are initial costs only and do not reflect any investment that is necessary to prepare a platform for the QP surface. A responsible cost comparison between any technologies should be made on a cost-per-year basis. These annualized cost figures will depend on reliable estimates of service life. Those estimates are a key objective of the remaining program of research.

**Table ES1. Average Initial Costs and Total Quantities for Each Quiet Pavement Technology: 2011/2012**

| Technology Description | Average Initial Costs ($) | | Total Quantities | |
|---|---|---|---|---|
| | Per Ton | Per Square Yard | Tons | Square Yards |
| AR-PFC 9.5 | 125.81 | 5.77 | 7,553 | 164,930 |
| PFC 9.5 | 116.00 | 5.32 | 10,394 | 228,020 |
| AR-PFC 12.5 | 128.00 | 12.80 | 4,341 | 43,410 |
| PFC 12.5 | 110.33 | 10.11 | 12,082 | 131,833 |
| CDG | N/A | 6.86 | N/A | 80,861 |
| NGCS | N/A | 10.84 | N/A | 42,434 |

PFC = porous friction course; AR = rubber-modified binder; CDG = conventional diamond grinding; NGCS = Next Generation Concrete Surface.

## Ongoing Activity

Researchers will continue to monitor the *functional* (e.g., noise, friction, ride quality) performance of the installed technologies through at least 2015. Fall 2013 performance testing is also expected to include more in-depth *structural* tests of the material and overall pavement systems.

Virginia is one of many partner states that sponsored the 2012 rebuild of the NCAT Pavement Test Track. Virginia will not only receive regular performance feedback on the

Virginia QP sections but will also have ready access to early findings from similar experiments at the test track sponsored by other states. The sections from other states are designed to provide answers regarding purported material and bond-related failures. To the extent that any of these issues might relate to Virginia's evaluation program, this research will be ready to adopt suitable solutions quickly.

Another element of the evaluation program will be a trial vacuum-sweeping regimen to determine if it extends the functional advantages of porous surfaces. The bi-directional nature of the 2011/2012 projects will make it possible to perform the vacuum maintenance in one direction only and use the other direction as a control to determine whether the maintenance is effective.

Finally, researchers will continue to monitor federal legislative and regulatory developments in the area of QP technology. In particular, researchers will focus on monitoring the extent to which federal law and regulations may begin to consider QP technology more favorably as a viable alternative to noise walls or sound barriers as a sound mitigation measure.

# INTRODUCTION

## Background

Traffic-generated noise comes from many sources, including vehicle engines and drive-trains, exhaust, aerodynamics, and the interaction of the tire with the pavement. The degree to which each of these sources factors into the overall noise picture depends on the kinds of vehicles in the traffic stream; the kinds of movement activities underway at a given location (e.g., acceleration, deceleration); and the average travel speeds. When these travel speeds exceed 35 mph and the traffic stream is made up primarily of free-flowing passenger vehicles and light trucks, the predominant source of noise is the tire-pavement interaction.[1] The amount of noise generated at this interface is further dependent on characteristics of the tire and the pavement surface. With regard to the traveled surface (i.e., pavement), the characteristics known to affect noise the most include (in decreasing order of significance) the surface texture, openness or porosity, and stiffness. The contribution from each characteristic is complicated, but in most instances a lower-noise pavement (i.e., a "quiet pavement" [QP]) will have a small negative texture (i.e., stone particles will not stick up from the surface), high openness or porosity, and relatively low stiffness. With regard to comparative noise levels, it takes about 3 decibels (dB) of difference for a change to be "noticeable"; a 5 dB change is considered "readily noticeable."[1]

The research program of the Virginia Department of Transportation (VDOT) has been exploring QP technologies since 2004. This early work involved participation in a multi-state survey by the National Center for Asphalt Technology (NCAT) at Auburn University in Auburn, Alabama, to compare common pavement surfaces in terms of relative tire-pavement noise production.[2]

## Legislation

The 2011 Session of the Virginia General Assembly brought a new focus to QP. In particular, Chapter 790 of the 2011 Virginia Acts of Assembly (*Code of Virginia* § 33.1-223.2:21; see Appendix A) directs "the Department" (i.e., VDOT) to

> expedite the development of quiet pavement technology such that applicable contract solicitations for paving shall include specifications for quiet pavement in any case in which sound mitigation is a consideration. To that end, the Department shall construct demonstration projects sufficient in number and scope to assess applicable technologies.

Chapter 790 further directs VDOT to evaluate the installed technologies and provide an interim report in June 2012 and a final report in June 2013. This final report is to include

> results of demonstration projects in Virginia, results of the use of quiet pavement in other states, a plan for routine implementation of quiet pavement, and any safety, cost, or performance issues that have been identified by the demonstration projects.

In the fall of 2012, VDOT requested a 2-year extension of the deadline to provide the final report to the Governor and the General Assembly and asked to be able to submit a second interim report on June 30, 2013. The extremely mild 2011/12 winter made it difficult to assess the expected performance of the QP materials in a typical Virginia winter. Moreover, results from the accelerated trafficking tests at NCAT were not expected until fall 2014 at the earliest. Extension of the study period was expected to allow a more realistic exposure of the 2011 QP technologies and essential additional experience based on the 2012 activity.

In January 2013, House Bill 2040, which requested the additional interim report and extended the deadline for a final report to June 30, 2015, was introduced. On March 6, 2013, these changes were enacted as Chapter 120 of the 2013 Virginia Acts of Assembly (see Appendix B).

## Interim Report: June 2012

The first interim report was delivered to the General Assembly in June 2012.[3] It described the selection of lower-noise pavement technologies ( i.e., the QP technologies); the development and construction of the first season (2011) of QP demonstration projects; and the evaluation tools and analysis that were used to compare the performance of the alternative technologies. The selected QP technologies included three asphalt surface materials and two mechanically applied finishes for concrete pavement. The three *asphalt* materials included two open-graded asphalt concrete mixtures that used a polymer-modified binder and one that used a similar aggregate gradation but with a rubber-modified binder. The two QP concrete technologies were conventional diamond grinding (CDG) and the Next Generation Concrete Surface (NGCS), which is diamond grinding followed by a "flush-grind" operation and then a final longitudinal grooving step.

After one winter of service, the asphalt technologies were *measurably* (2 dB or less) less noisy than the control surfaces on average and *noticeably* (≥3 dB) more quiet in several specific cases. The concrete technology NGCS maintained a *readily noticeable* (≥5 dB) noise advantage over the control concrete surface. A comparison with the results of the late fall 2011 tire-pavement noise testing showed that none of the surfaces had become louder over the very mild winter.

The QP technologies had a more distinct advantage over the control surfaces with regard to ride quality. The initial ride quality of the NGCS was exceptional, and contractors earned smoothness incentives with the quiet asphalt materials, including the materials placed at thinner (1 inch) application rates. All of the QP surfaces had excellent skid resistance and received consistent recognition for their wet-weather service (i.e., low splash and spray).

## 2012 Activity

Summer and fall 2012 activities included installation of two trial sections at the NCAT Pavement Test Track (www.pavetrack.com). The raw materials from the most promising 2011 asphalt demonstration technologies were sent to NCAT, blended with standard materials to produce "Virginia" QP technologies, and placed on the NCAT Pavement Test Track. Components of these promising technologies were also brought together to create two more demonstration projects in Virginia, one in the Northern Virginia District and the other in the Culpeper District.

## PURPOSE AND SCOPE

This report is the second in a series of documents that chronicle the selection of lower-noise pavement technologies; the development and construction of demonstration projects; and the evaluation tools and analysis being used to compare the performance of the alternative technologies. This second interim report is particularly focused on the additional QP sections that were constructed in 2012 and also provides the status of the performance of the 2011 series of demonstration projects. The 2012 construction activities involved two new projects on Virginia roadways and two sections on the NCAT Pavement Test Track.

## METHODS

### Selection of Technologies for 2012 Demonstration

Early feedback from the 2011 QP demonstration projects helped researchers identify candidate technologies for additional pilot projects for the 2012 construction season. These preliminary findings were also instrumental in the selection of the technologies that are being subjected to accelerated trafficking at NCAT. Since none of the materials and treatments from 2011 had premature material failures or essential functional problems (such as low winter skid resistance), tire-pavement noise performance served as the key discriminator for determining which technologies to pursue. The primary qualification to become a candidate demonstration project remained unchanged: tire-pavement noise was and would continue to be the predominant source of traffic-generated noise, and thus the traffic at the location of the demonstration project should be relatively free flowing and generally 35 mph and higher.

### Functional Evaluation

Evaluation of the original (2011) demonstration projects, as well as the assessment of the new 2012 projects, continues to focus on tire-pavement noise performance. Secondary testing to assess comfort and safety characteristics is also part of the regular regimen of tests. A complete description of each test method is included in the first interim report.[3] A brief summary of each test is provided here.

#### Tire-Pavement Noise

Tire-pavement noise is monitored using measurements made in accordance with AASHTO TP 76-12 (Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity

[OBSI] Method).[4] The standard test speed is 60 mph, and the standard test length covers 5 seconds of travel (440 feet at 60 mph). The sound intensity level is measured with microphones that are mounted near the tire-pavement interface. A valid and complete set of runs requires three tests, the results of which must be within an acceptable range of variability. The resulting sound intensity level is reported in A-weighted decibels, or dB(A). Each QP section is tested once in the fall and then again in the spring.

## Ride Quality

Ride quality is monitored and summarized using the International Roughness Index (IRI), a standard index that is generated in accordance with ASTM E1926. Higher IRI values suggest rougher surfaces, and lower values indicate smoother pavements. At this point, ride quality testing on the surfaces has been conducted only when they were new.

## Texture and Resistance to Skidding

Texture and friction properties have been measured with several different technologies throughout the project. Initial texture measurements were made with the Circular Track Meter in accordance with ASTM E2157. Because this test requires lane closure, all texture tests after the spring 2012 round of testing will be conducted with a high-speed device in accordance with ASTM E1845 (Figure 1a). Friction and texture tests are conducted during the spring round of OBSI noise tests. Unfortunately, this high-speed texture technology was just becoming available to researchers as of this writing and results for spring 2013 are not yet available.

The requirement for lane access (and closure) also explains why the Dynamic Friction Tester, as described in ASTM E1911 was retired after the initial round of testing. The initial (spring 2012) series of full-scale, high-speed friction tests were conducted with both the GripTester in accordance with ASTM E2340 and a locked wheel tester in accordance with ASTM E274. Monitor testing since that time has been conducted exclusively with the GripTester (Figure 1b). The 2013 cycle of friction tests was conducted in early spring shortly after the OBSI noise tests.


**(a) Roline Laser Scanner** **(b) GripTester (GT)**

**Figure 1. Devices for Collecting Texture and Friction Data: (a) Roline Laser Scanner for measuring profile and texture; (b) GripTester for measuring continuous friction.**

### Winter Performance

The interaction of QP technologies and winter weather and maintenance continues to be a priority of the evaluation. Guidelines for maintenance and observation were distributed to field maintenance officials prior to the winter of 2011/12.[3] Although no new guidelines were distributed for the 2012/13 winter, researchers remain in contact with local maintenance administrators.

## FINDINGS AND DISCUSSION

### Candidate Quiet Pavement Technologies

As of spring 2013, the QP demonstration projects incorporated four asphalt technologies and two mechanically applied finishes to hydraulic cement concrete pavements.

### Asphalt

The four quiet asphalt materials are open-graded asphalt concrete mixtures. Two of these technologies were designed and produced using a 3/8-inch (9.5-mm) top-size stone. The other two use a slightly coarser ½-inch (12.5-mm) top-size stone. The general aggregate structure of the fine and coarse mixtures was maintained and the binder was modified with ground tire rubber to produce the third and fourth low-noise asphalt technologies. The finer mixtures were placed at a thickness of approximately 1 inch, and the coarser mixtures at a thickness of 2 inches. The conventional mixtures (non-rubber binder) were designed in accordance with VDOT's *Special Provision for Porous Friction Course* (PFC).[5] The rubber-modified mixtures complied with the requirements of VDOT's *Special Provision for Asphalt Rubber Porous Friction Course* (AR-PFC).[6]

Early success with rubber modification of the open-graded mixtures led researchers to explore rubber modification of two control mixtures for the 2012 trials. To that end, VDOT accepted a value engineering proposal from an asphalt producer to use ground tire rubber in lieu of conventional polymer modification for two stone matrix asphalt (SMA) mixtures. As with the PFC mixtures, one of the rubber-modified "control" mixtures was a fine gradation mixture (top-size stone of 3/8 inch) and the other a coarser gradation mixture (top-size stone of ½ inch).

### Concrete

As noted previously, the two lower-noise concrete technologies included CDG and NGCS. The CDG surface was achieved in accordance with VDOT's *Special Provision for Grinding Concrete Pavement*.[7] The NGCS used the newly developed VDOT *Special Provision for Grinding Next Generation Concrete Pavement Surface*.[8]

## Demonstration Projects

VDOT used these six candidate QP technologies in five QP demonstration projects in 2011 and two more in the summer of 2012 (see Figure 2). Projects 1 through 5 were described in detail in the first interim report.[3] Project 6 is on the Fairfax County Parkway, runs from Franklin Farm Road to Rugby Road, and covers both the northbound and southbound directions. The surface from Franklin Farm Road to Stringfellow Road (northernmost portion) is a rubberized SMA. The surface from Stringfellow Road to Rugby Road (southern end) is the coarser-graded rubberized PFC. Both materials were placed at a thickness of 2 inches. Project 7 is located on US 17, begins near the intersection with I-66 near Marshall, and runs in the southbound lanes for a little over 5 miles. The first half of the project is a conventional finer-graded SMA, and the second half is a rubber-modified version of the same finer-graded SMA. These materials were placed at a thickness of 1½ inches. Appendix C provides a more detailed location map for each of the 2012 projects.

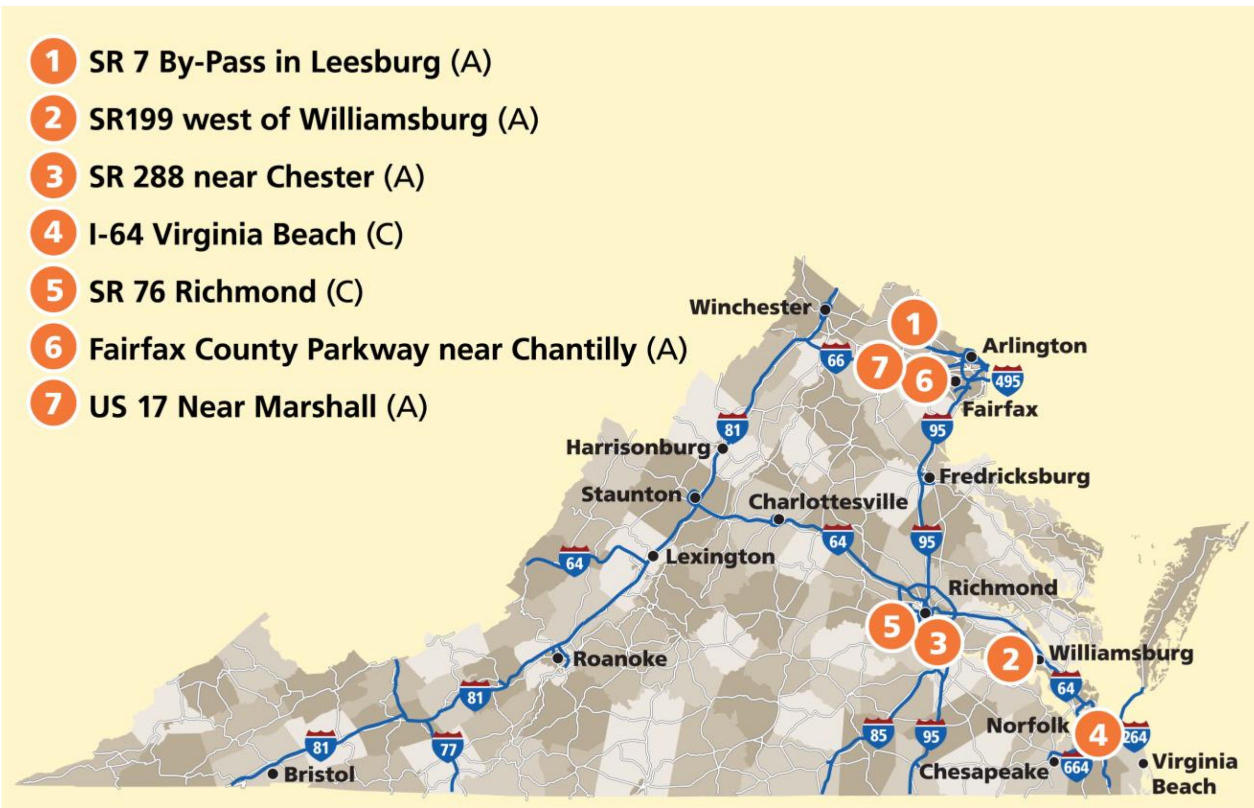

**Figure 2. Locations for 2011 and 2012 Quiet Pavement Demonstration Projects. A = asphalt; C = concrete.**

## NCAT Test Sections

Survivability of QP technologies under heavy traffic is also very important. To learn as much as possible in as short a time as possible about how Virginia materials would perform under heavy loads, VDOT installed two sections of QP materials in late summer 2012 on the NCAT Pavement Test Track. There, the materials receive the equivalent of 10 years of heavy traffic loading in just 2 years. Researchers at NCAT continuously monitor the performance of the test sections and provide periodic updates to partner states. In addition to conventional pavement performance indicators such as rutting and cracking, NCAT staff monitors ride quality and tire-pavement noise.

Figure 3 is a plan view of the track. The two Virginia QP sections are located in the southwest corner of the track. The technologies used for those sections incorporate components of the best performing materials from the 2011 demonstration projects. The first, installed in Section W-10, was material with the lowest overall average results of the OBSI noise tests from the 2011 demonstration projects. The second, installed in Section S-1, combined the characteristics of the first material with a component (ground tire rubber) that was present in the single lowest noise demonstration section from 2011.

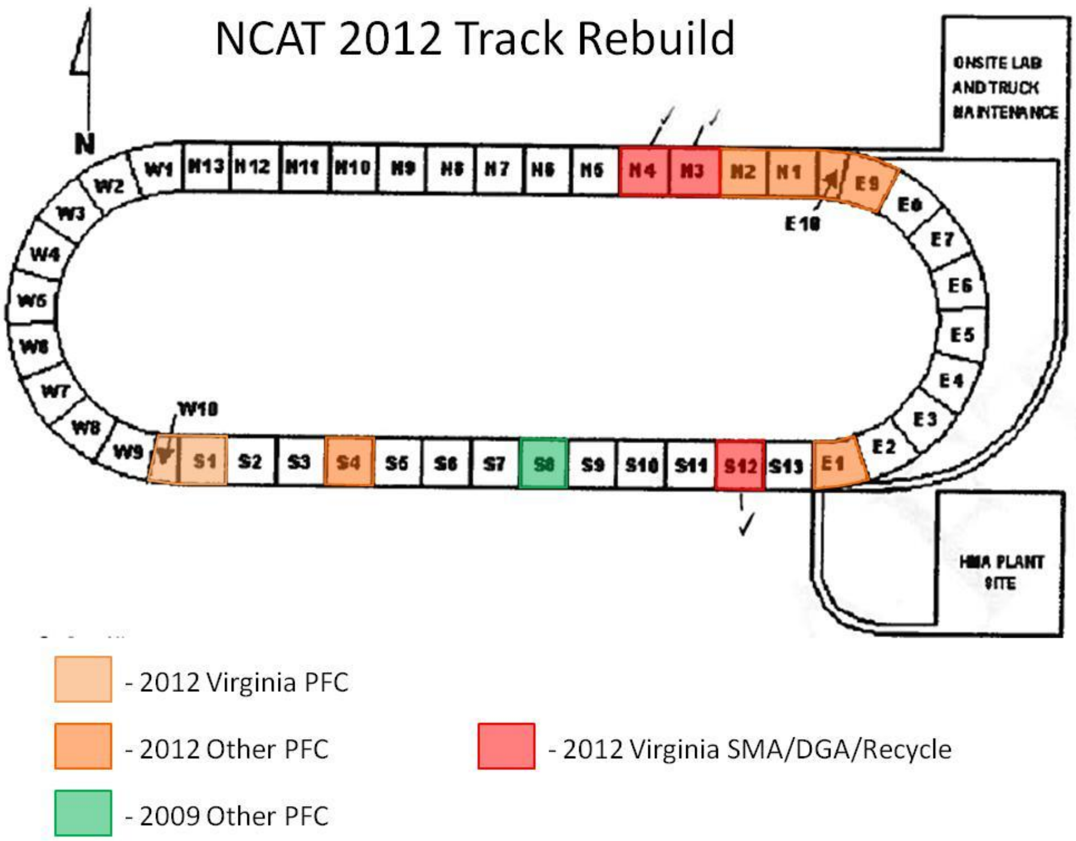


**Figure 3. Virginia Quiet Pavement Technologies on 2012 NCAT Pavement Test Track. NCAT = National Center for Asphalt Technology; PFC = porous friction course; SMA = stone matrix asphalt; DGA = dense-graded asphalt.**

## Functional Evaluation

### Tire-Pavement Noise

*2012 Projects: Initial Results*

The two new demonstration projects for 2012 incorporated three possible new QP technologies. The first and most promising was the AR-PFC 12.5 technology. The other two were SMA mixtures with rubber modification: AR-SMA 9.5 and AR-SMA 12.5. To determine which, if any, of these new technologies would qualify as a lower-noise material, the results of the new-surface OBSI noise tests were compared to those from the original series of 2011 projects. Figure 4 summarizes this comparison. As new surfaces, the 2011 quiet asphalt technologies averaged an intensity level of approximately 99 dB(A), and the control (typical) surfaces averaged approximately 102 dB(A). The rubber modification of the 2012 SMA mixtures provided no obvious tire-pavement noise advantage, as the intensity levels were as high as or higher than the overall control values from 2011. The rubber-modified PFC 12.5 material, however, showed considerable promise as a low-noise material.

Initial results of the OBSI noise tests for the NCAT trial sections were consistent with those for similar materials from the 2011 and 2012 Virginia demonstration projects. The PFC 12.5 and AR-PFC 12.5 sections installed on the test track had new-surface OBSI noise values of 94.5 and 94 dB(A), respectively.

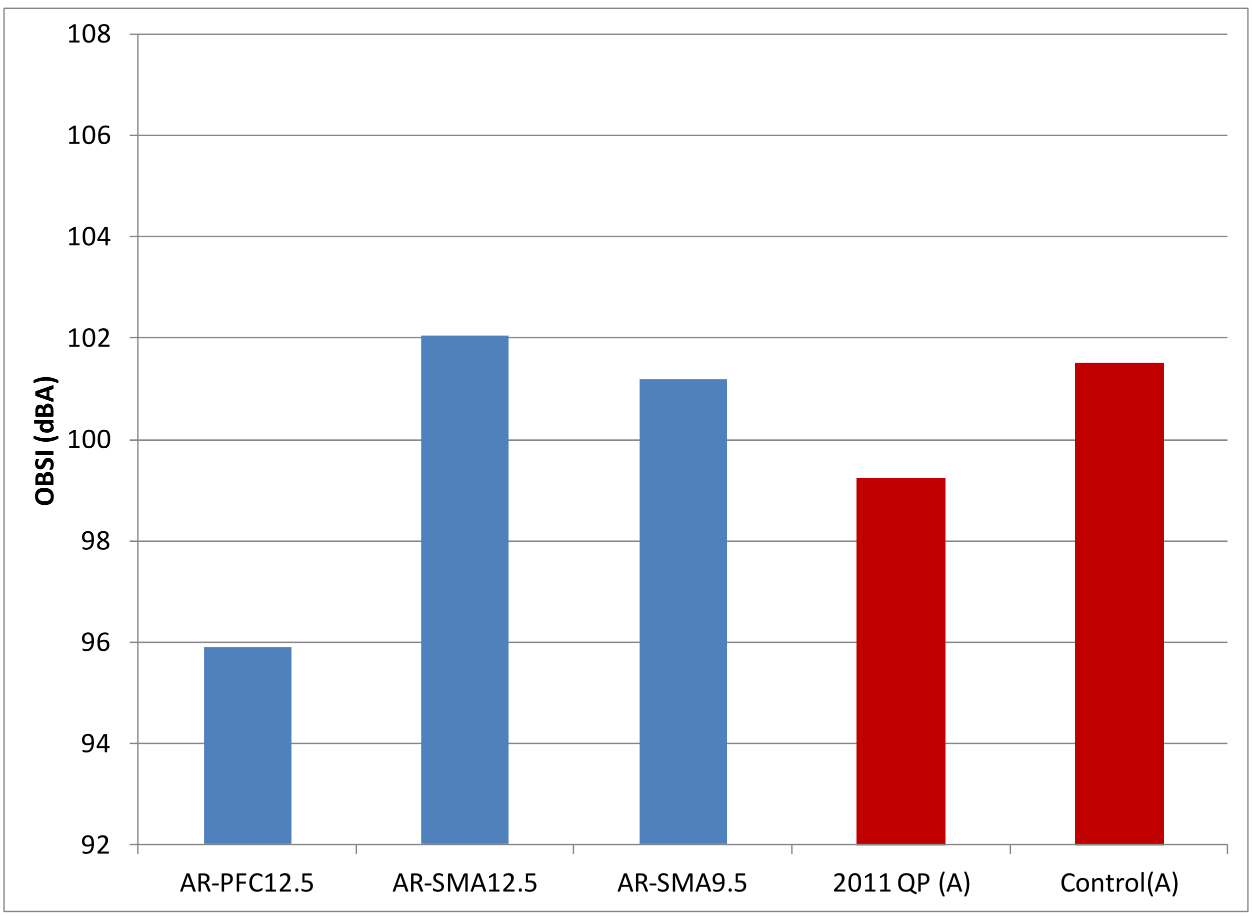


**Figure 4. Average OBSI Noise Measurements: 2012 Demonstration Materials (blue) Versus 2011 QP Materials and Overall Program Asphalt Control (red). OBSI = On-Board Sound Intensity; QP = quiet pavement.**

*Acoustic Longevity*

Achieving initial noise reduction is important, but sustaining that reduction is essential to controlling the agency costs of an effective QP program. As of May 2013, a tire-pavement noise survey had been conducted four times for the 2011 demonstration projects and twice for the two sections installed in 2012. OBSI noise testing for the original demonstration projects, therefore, now reflects two winters of exposure to weather and traffic.

Figure 5 tracks the average OBSI noise value by surface technology for the timeframe that began with completion of the 2011 series of demonstration projects. It also includes typical values for concrete and asphalt, as determined through similar testing of the respective control surfaces. The quiet concrete surfaces have a slight downward trend in tire-pavement noise, but this should be expected. The process that creates both surfaces (CDG and NGCS) initially leaves thin ridges of concrete that remain following grinding with diamond-impregnated blades. As these ridges break off under traffic, the texture diminishes slightly and a small early-life reduction in tire-pavement noise is likely. Since most of these ridges were likely worn away during the first few months of traffic, this decrease is not expected to continue.

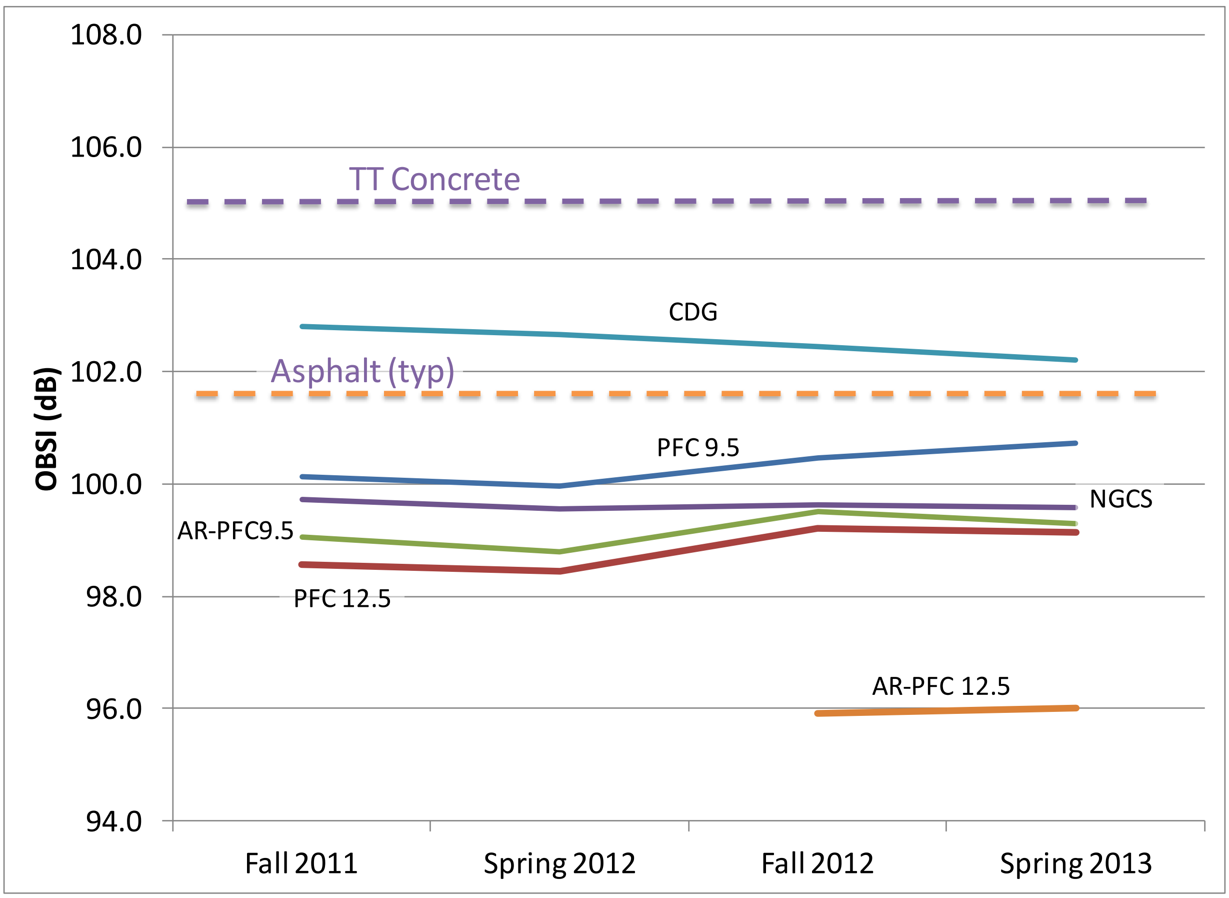


**Figure 5. OBSI Noise Value Trends With Time: Quiet Pavement Technologies and Typical Concrete and Asphalt Surfaces. OBSI = On-Board Sound Intensity; TT = transverse tined; CDG = conventional diamond grind; (typ) = typical; PFC = porous friction course; NGCS = Next Generation Concrete Surface; AR = rubberized-modified asphalt.**

OBSI noise values for the asphalt surfaces have a slightly upward trend, but this is also to be expected. As the pores in these materials become clogged, their ability to absorb noise decreases. Although none of the measured increases is perceptible with human hearing, the noise value for the PFC 9.5 material appears to be trending upward at the fastest rate. As the finer of the porous mixtures, the voids in this material are likely smaller and more susceptible to clogging.

**Resistance to Skidding**

The results of the spring 2013 GripTester survey for tire-pavement friction are shown in Figure 6. In addition to the average results for each QP technology, the graph includes typical values for concrete and asphalt, again as measured on the respective control surfaces. There remain no apparent wet-skid issues in the matrix of QP technologies. The newest surface, the AR-PFC 12.5 surface, had a lower grip number than the other quieter asphalt surfaces, but lower early-life friction numbers are typical with asphalt surfaces. The NGCS had the lowest friction values in the demonstration program. Based on common friction values, these lower numbers do not represent a safety concern but should also be anticipated. The NGCS is, after all, the most heavily machined surface in the program.

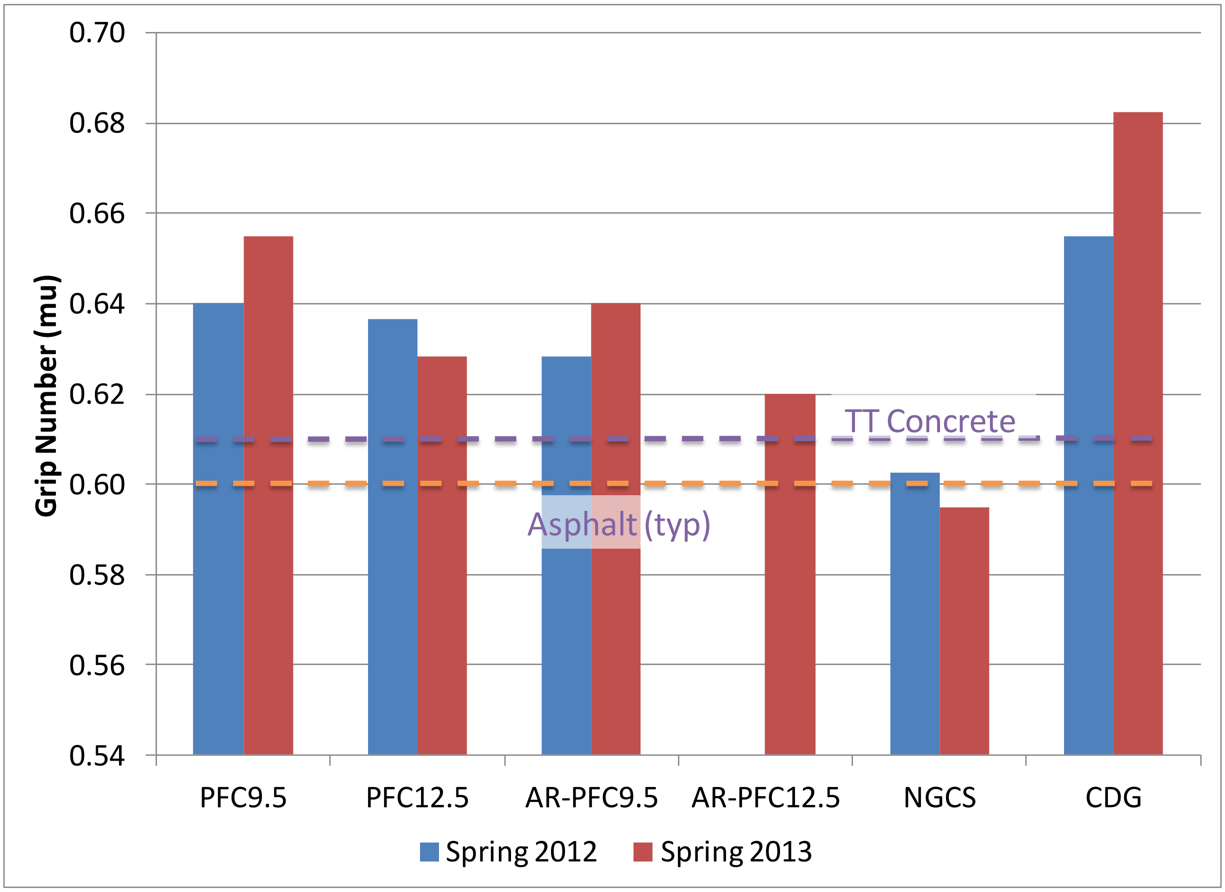


**Figure 6. Tire-Pavement Friction Values for Virginia Quiet Pavement Surfaces: Spring 2012 Versus Spring 2013. TT = transversely tined; TT = transverse tined; CDG = conventional diamond grind; (typ) = typical; PFC = porous friction course; NGCS = Next Generation Concrete Surface; AR = rubberized-modified asphalt.**

## Winter Performance

Winter 2012/13 was the second opportunity for Virginia maintenance crews to work with the combination of PFC materials and frozen precipitation. Although cooler than the previous winter, it was still the 18th warmest on record[9] and the only frozen precipitation came late in the season. No information was received that reflected performance issues that were not noted in the previous year. The porous materials continued to cool more efficiently (i.e., "freeze" earlier) and maintenance crews addressed this with slightly earlier and additional applications of deicing chemicals.

# Costs and Quantities

Table 1 is an update of the costs and quantities associated with the demonstration projects to reflect the additional QP technologies for 2012. Since the asphalt technologies are placed at varying thicknesses and the concrete technologies simply "refinish" the existing surface, the cost figures are normalized to an average per-surface-area cost (i.e., per square yard). There are some important qualifications the reader should bear in mind when considering and comparing these costs. These costs apply only to the surface material or finishing technique. Any additional preparation (e.g., binder layers, patching, etc.) will add to this cost. The asphalt control (SMA) costs are not included because SMA materials can theoretically serve as both a top structural layer and a wearing surface; the PFC mixtures are wearing surface mixtures only. These projects are also, by definition, demonstration projects and, therefore, not routine construction. Limited production of even conventional materials or processes will make it difficult to realize any economies of scale. That impact is exacerbated when the material or process is experimental. Reliable cost-comparison analyses will require experience with full-production use of these technologies. Even then the analysis will need to reflect project-specific characteristics.

A responsible cost comparison between any alternatives should be made on a cost-per-year basis. These annualized cost figures will depend on reliable estimates of service life. These estimates are a key objective of the remaining program of research.

**Table 1. Average Initial Costs and Total Quantities for Each Quiet Pavement Technology: 2011/2012**

| Technology Description | Average Initial Costs ($) | | Total Quantities | |
|---|---|---|---|---|
| | Per Ton | Per Square Yard | Tons | Square Yards |
| AR-PFC 9.5 | 125.81 | 5.77 | 7,553 | 164,930 |
| PFC 9.5 | 116.00 | 5.32 | 10,394 | 228,020 |
| AR-PFC 12.5 | 128.00 | 12.80 | 4,341 | 43,410 |
| PFC 12.5 | 110.33 | 10.11 | 12,082 | 131,833 |
| CDG | N/A | 6.86 | N/A | 80,861 |
| NGCS | N/A | 10.84 | N/A | 42,434 |

PFC = porous friction course; AR = rubber-modified binder; CDG = conventional diamond grinding; NGCS = Next Generation Concrete Surface.

## SUMMARY AND NEXT STEPS

### Early Observations

Four quiet asphalt and two quiet concrete technologies have now been installed in seven demonstration projects. The quiet asphalt technologies are four PFC mixtures: two with semi-conventional asphalt binders and two with a rubber-modified asphalt binder. The quiet concrete technologies include a CDG surface and the NGCS, created with a combination grind and groove process designed specifically to reduce noise on concrete pavements. As of spring 2013, the difference in measured tire-pavement noise between the control surfaces and the most successful (lowest noise) quiet asphalt technology was *readily noticeable* (≥5 dB). The NGCS noise advantage over the standard concrete pavement surface also continued to be *readily noticeable* (≥5dB). The noise of the quiet concrete surfaces appears to have slightly decreased since first installed, whereas that of the quiet asphalt materials has slightly increased. In neither case is the difference perceptible to human hearing. All of the surfaces continue to have good resistance to skidding. There have also been no reports of unique safety concerns associated with winter weather, and local maintenance crews have been proactive when addressing freezing precipitation on the porous surfaces.

### Ongoing Activity

#### Existing Demonstration Projects

Researchers will continue to monitor the *functional* performance of the installed technologies through at least 2015. The *functional* monitoring will include a twice annual, spring and fall, OBSI noise survey. The spring round of tests will also capture tire-pavement friction, profile (for ride quality), and texture. These additional tests will not only ensure that the surfaces remain safe but will also allow researchers to understand what other changes happen at the surface as (and if) tire-pavement noise changes with age.

Fall 2013 performance testing is also expected to include more in-depth tests of the material and overall pavement system in the asphalt projects. In particular, researchers will collect specimens of the QP surface materials and the material underlying these materials. These limited destructive tests will make it possible to determine how, for instance, the void structure of the porous materials is changing with age and under traffic. Specimens that include both the surface and underlying layer will permit testing of the bond strength, a property considered especially important for the thinner and lighter applications. Finally, strength tests of the underlying material will be used in an attempt to determine whether the porous surface materials are having any effects on material degradation of the deeper pavement structure.

#### NCAT Test Sections

Virginia is one of many partner states that sponsored the 2012 rebuild of the NCAT Pavement Test Track. As discussed previously, Virginia will not only receive regular performance feedback on the Virginia QP sections but will also have ready access to early findings from similar experiments sponsored by other states. There are six other new PFC surfaces in the 2012 rebuild of the test track and one remaining from 2009 (see Figure 3). The sections from other states are designed to provide answers regarding purported material and bond-related failures. To the extent that any of these issues might relate to Virginia's evaluation program, this research will be ready to adopt suitable solutions quickly.

### Maintenance of Porous Surfaces

There is considerable commercial literature recommending aggressive maintenance of porous parking lots to maintain porosity.[10,11] It is not clear, however, if the philosophy adopted for parking lots translates directly to high-speed roadways with similar surface materials (i.e., PFCs). Researchers in Europe and Asia have found success in maintaining porosity of roadway pavements through high-pressure water blasting and vacuuming,[12] whereas others have suggested that the action of high-speed traffic on wet PFC surfaces is sufficient to maintain adequate porosity.[13] An element of the ongoing Virginia evaluation program is a trial of a regular vacuum-sweeping regimen to determine if it extends the functional advantages of porous surfaces. The bi-directional nature of the 2011/2012 projects will make it possible to perform the vacuum maintenance in one direction only and use the other direction as a control to determine whether the maintenance is effective. Winter maintenance practices will also continue to be a focus for the next 2 years.

### Monitoring Federal Developments

For the remainder of the study period, researchers will continue to monitor federal legislative and regulatory developments in the area of QP technology. In particular, researchers will focus on monitoring the extent to which federal law and regulations may begin to consider QP more favorably as a viable alternative to noise walls or sound barriers as a sound mitigation measure.

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## APPENDIX A

## CHAPTER 790

*An Act to amend and reenact § 33.1-223.2:21 of the Code of Virginia, relating to highway noise abatement practices, technologies, and pavement standards.*

[H 2001]
Approved April 6, 2011

Be it enacted by the General Assembly of Virginia:

1. That § 33.1-223.2:21 of the Code of Virginia is amended and reenacted as follows:

§ 33.1-223.2:21. Noise abatement practices and technologies.

*A.* Whenever the Commonwealth Transportation Board or the Department plan for or undertake any highway construction or improvement project and such project includes or may include the requirement for the mitigation of traffic noise impacts, consideration should be given to the use of noise reducing design and low noise pavement materials and techniques in lieu of construction of noise walls or sound barriers. Landscaping in such a design would be utilized to act as a visual screen if visual screening is required.

*B. The Department shall expedite the development of quiet pavement technology such that applicable contract solicitations for paving shall include specifications for quiet pavement in any case in which sound mitigation is a consideration. To that end, the Department shall construct demonstration projects sufficient in number and scope to assess applicable technologies. The assessment shall include evaluation of the functionality and public safety of these technologies in Virginia's climate and shall be evaluated over two full winters. The Department shall provide an interim report to the Governor and the General Assembly by June 30, 2012, and a final report by June 30, 2013. The report shall include results of demonstration projects in Virginia, results of the use of quiet pavement in other states, a plan for routine implementation of quiet pavement, and any safety, cost, or performance issues that have been identified by the demonstration projects.*

**APPENDIX B**

**CHAPTER 120**

*An Act to amend and reenact §* 33.1-223.2:21 *of the Code of Virginia, relating to noise abatement practices and technologies.*

[H 2040]
Approved March 6, 2013

Be it enacted by the General Assembly of Virginia:

1. That § 33.1-223.2:21 of the Code of Virginia is amended and reenacted as follows:

§ 33.1-223.2:21. Noise abatement practices and technologies.

*A.* Whenever the Commonwealth Transportation Board or the Department plan for or undertake any highway construction or improvement project and such project includes or may include the requirement for the mitigation of traffic noise impacts, consideration should be given to the use of noise reducing design and low noise pavement materials and techniques in lieu of construction of noise walls or sound barriers. Landscaping in such a design would be utilized to act as a visual screen if visual screening is required.

*B.* The Department shall expedite the development of quiet pavement technology such that applicable contract solicitations for paving shall include specifications for quiet pavement in any case in which sound mitigation is a consideration. To that end, the Department shall construct demonstration projects sufficient in number and scope to assess applicable technologies. The assessment shall include evaluation of the functionality and public safety of these technologies in Virginia's climate and shall be evaluated over *at least* two full winters. The Department shall provide an *initial* interim report to the Governor and the General Assembly by June 30, 2012, *a second interim report by June 30, 2013,* and a final report by June 30, ~~2013~~ *2015*. The report shall include results of demonstration projects in Virginia, results of the use of quiet pavement in other states, a plan for routine implementation of quiet pavement, and any safety, cost, or performance issues that have been identified by the demonstration projects.

# APPENDIX C

## 2012 QUIET PAVEMENT DEMONSTRATION PROJECTS: DETAILED LOCATION AND TECHNOLOGY LIMITS

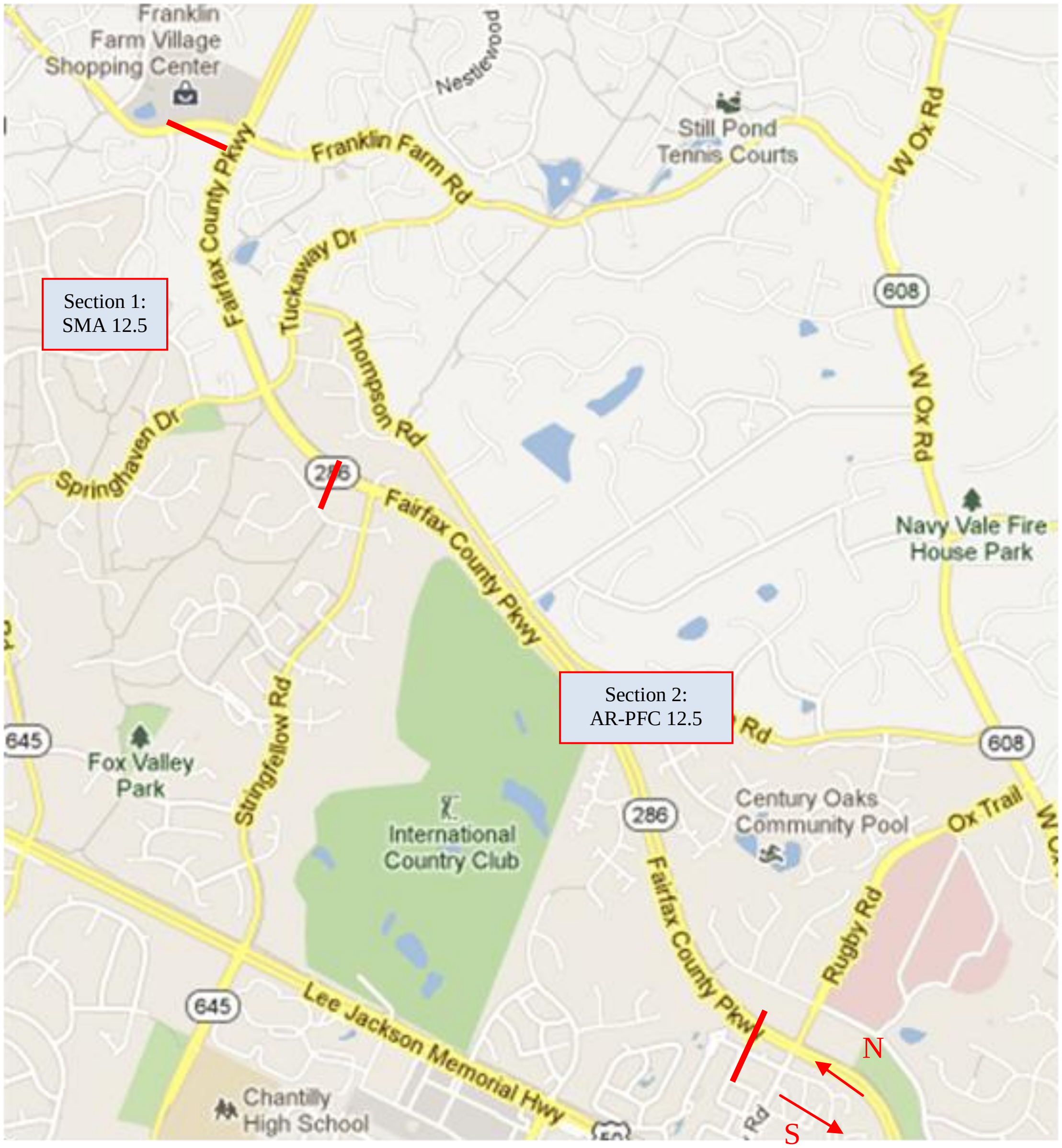


**Figure C1. Route 286 Quiet Asphalt Project.**


**Figure C2. US 17 Quiet Asphalt Project.**