REPORT OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION

The Virginia Quiet Pavement Implementation Program Under Section 33.2-276 of the Code of Virginia - Final Report - June 2015

TO THE GOVERNOR AND THE GENERAL ASSEMBLY OF VIRGINIA

HOUSE DOCUMENT NO. 13

COMMONWEALTH OF VIRGINIA
RICHMOND
2015

COMMONWEALTH of VIRGINIA

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

Charles A. Kilpatrick, P.E.
Commissioner

November 12, 2015

The Honorable Terry McAuliffe
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. In 2014, all of these requirements for the study were re-codified as Va. Code § 33.2-276.

The attached document is the final report required by Chapter 790 and Chapter 120. This report summarizes overall condition, functional performance (ride, noise, friction), winter maintenance and use characteristics, and other observations relating to quiet pavement technology, after as much as four winters under traffic. The report also summarizes results from accelerated trafficking of Virginia quiet pavement materials at the National Center for Asphalt Technology Test Track from fall 2012 to late fall 2014. Finally, the report reviews current federal policy on noise mitigation strategies, highlights relevant findings from important recent research, provides a status of national and international activities, and offers conclusions and recommendations as to Virginia's way forward with respect to implementation of lower-noise pavement.

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

Sincerely,

Charles A. Kilpatrick, P.E.

Attachment

cc: The Honorable Aubrey L. Layne

THE VIRGINIA QUIET PAVEMENT IMPLEMENTATION PROGRAM UNDER SECTION 33.2-276 OF THE *CODE OF VIRGINIA* FINAL REPORT

Virginia Center for Transportation Innovation and Research
As of June 2015

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EXECUTIVE SUMMARY

Introduction

Section 33.2-276 of the *Code of Virginia* 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 mitigation is a consideration. The statute 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. Finally, §33.2-276 requires VDOT to 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, 2015 and provides that 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.

It is noted that the original 2013 deadline for a final report was extended for 2 years, primarily to allow for two additional winters of experience with the demonstration projects. The extension also allowed for completion of an accelerated trafficking experiment with two of the technologies, as well as additional time for federal authorities to consider the viability of quiet pavement as a noise mitigation measure.

Purpose and Scope

The purpose of this study was to comply with the direction provided by Chapter 790 of the 2011 Virginia Acts of Assembly (*Code of Virginia* § 33.1-223.2:21, recodified as § 33.2-276). This statute directs VDOT to construct demonstration projects that incorporated quiet pavement technologies, assess their ability to reduce transportation noise, and evaluate the functionality and public safety ramifications of these technologies in Virginia's climate. This document is the final in a series of reports that chronicled the selection of the lower-noise pavement technologies; the development and construction of demonstration projects; and the evaluation tools and analysis used to compare the performance of the alternative strategies. This report summarizes overall condition, functional performance (ride, noise, friction), winter maintenance and use characteristics, and other observations after as much as four winters under traffic. The report also summarizes results from accelerated trafficking of Virginia quiet pavement materials at the National Center for Asphalt Technology (NCAT) Test Track from fall 2012 to late fall 2014. Finally, the report reviews current federal policy on noise mitigation strategies, highlights relevant findings from important recent research, provides a status of national and international activities, and offers conclusions and recommendations as to Virginia's way forward with respect to implementation of lower-noise pavement.

Methods

Much of the approach adopted to meet the objectives of this research was developed with the guidance of the Quiet Pavement Task Force (QPTF), an expert working group consisting of members from VDOT's Materials, Maintenance, and Environmental Divisions; the Virginia Center for Transportation 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 worked with researchers to select the lower-noise materials and treatments to demonstrate. The Task Force also established key requirements of the demonstration projects, helped identify locations, and worked with VDOT districts and contractors to install the projects. The QPTF was also instrumental in the accelerated trafficking experiment at NCAT.

Functional evaluation focused on tire-pavement noise, but also included early community wayside noise testing. Secondary testing to assess safety and comfort characteristics included tire-pavement friction and high-speed profiling (for ride quality). Winter maintenance experience was elicited from VDOT and contractor maintenance superintendents with direct responsibility for the demonstration projects.

Findings and Discussion

As of spring 2015, the difference in measured tire-pavement noise between the control surfaces and the most successful (lowest noise) quiet asphalt technology was no longer detectable with normal human hearing (<3 dB). The lowest noise concrete surface continues to have a *noticeable* (approximately 4dB) advantage over the standard concrete finish. All of the surfaces continue to have good resistance to skidding and excellent ride quality. The quiet asphalt surfaces also continue to provide good splash-spray characteristics with better wet-weather visibility. Unfortunately, the openness or porosity that enables the lower noise and better wet-weather performance of these asphalt surfaces also make them quicker to cool and more difficult to clear of frozen precipitation. Freezing precipitation contributed to vehicles "sliding into the ditches" along one demonstration project (Route 7 Leesburg) in early 2014 and led to "multiple accidents" and a brief facility closure on another (Fairfax County Parkway) in March 2015 . Local maintenance crews also report the need to apply deicing treatments earlier and more often on all of the quiet asphalt projects.

Pursuant to federal regulation (23 CFR, Part 772) the Commonwealth Transportation Board adopted Virginia's State Noise Abatement Policy (SNAP) and pursuant to that policy, all transportation improvement projects developed in conformance with the Virginia Department of Transportation's guidelines must be in conformance with those federal highway traffic noise impact analysis and abatement procedures and guidance mandated by FHWA. The federal regulations require that at least fifty percent of the impacted receptors receive a 5 dB(A) or more reduction in noise through the abatement strategy. VDOT must also achieve and maintain a design goal (for *reasonableness*) of 7 dB(A) of reduction for at least one impacted receptor. Based on the results of testing and demonstration projects conducted in response to §33.2-276, QP technologies have not demonstrated the level of noise abatement required by federal regulations nor by VDOT guidelines developed in accord with the SNAP and federal regulations.

Federal regulations [23 CFR 772.15 (c)] also identify the abatement measures that are eligible for federal funding and QP technologies are not currently listed as eligible measures (*19*). Federal policy described in FHWA guidance memoranda (http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/) specifically precludes the use of pavement type or surface texture as a noise abatement measure. It further states that provisional policy changes would require research that demonstrated the safety, durability, and noise-reducing capacity of each ‘quiet pavement,’ and these characteristics would need to be maintained in perpetuity.

Conclusions and Recommendations

All of the QP technologies examined through this research offer functional advantages over more conventional materials and finishes. They are initially quieter, have excellent resistance to skidding, and exhibit superior ride quality. The quiet asphalt (PFC) materials also provide beneficial spray reduction and improved wet-weather visibility. However, PFCs require close monitoring and aggressive application of deicing chemicals to avoid specific safety hazards during winter weather events.

None of the QP technologies provided sufficient noise reduction to singularly satisfy federal regulations for noise abatement, nor do federal regulations and policy currently recognize QP technology as an appropriate noise abatement measure. Furthermore, the noise reducing capability of the Virginia QP materials diminish with time. Over the course of this study, there has been a slight increase in the tire-pavement noise of the quiet concrete surfaces and a substantial increase in the tire-pavement noise for the quiet asphalt materials.

VDOT is nonetheless encouraged to continue monitoring federal policy for changes that may incorporate pavement type as a tool for mitigating noise. VDOT should also continue to monitor (and trial as warranted) products of national and international research and development that show promise for reducing and/or eliminating the need for traditional sound barriers.

INTRODUCTION

Code of Virginia

Section 33.2-276 of the *Code of Virginia* provides, in relevant part:

> B. "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 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, 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."

Background

First Interim Report: June 2012

The first interim report was delivered to the General Assembly in June 2012 (*1*). 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 aggregate 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.

Second Interim Report: June 2013

The second interim report described two additional QP sections that were constructed in 2012 and provided an update on the performance of the 2011 technologies (*2*). The materials used in 2012 (responding to early feedback from the 2011 demonstrations) included a rubber modified coarse open-graded material and a rubber modification to a control mixture (i.e., rubber-modified stone matrix asphalt). The second interim report also describes the installation of two trial sections at the National Center for Asphalt Technology (NCAT) Pavement Test Track (www.pavetrack.com), which involved shipping raw materials from the most promising Virginia technologies to southeastern Alabama for accelerated trafficking.

PURPOSE AND SCOPE

This is the final in the series of reports that chronicled the selection of lower-noise pavement technologies; the development and construction of demonstration projects; and the evaluation tools and analysis used to compare the performance of the alternative strategies. This report summarizes overall condition, functional performance (ride, noise, and friction), winter maintenance and use characteristics, and other important observations made after up to four Virginia winters under traffic. The report also summarizes results from the accelerated trafficking of Virginia paving materials at the NCAT Test Track from fall 2012 to late fall 2014. The report reviews current federal policy and the pertinent ramifications for Virginia's program. It also highlights important findings from other recently completed and ongoing national programs of research.

Lastly, the report offers a series of recommendations regarding continued use of QP materials and treatments, as well as suggestions for future research and development concerning the relevance of QP technologies to reduce overall traffic noise.

METHODS

The Quiet Pavement Task Force

As the 2011 legislation began to take shape in the fall of 2010, VDOT and the Virginia paving industry formed the Quiet Pavement Task Force (QPTF) in an effort to address the legislation cooperatively as it became enacted into the *Code of Virginia*. The task force includes representatives from VDOT's Materials, Maintenance, and Environmental Divisions; 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 was responsible for a number of critical early-project activities and decisions. Members worked with VCTIR to conduct a review of literature and ongoing research. Further, the QPTF combined findings from the literature review with contemporary practical experience to develop a matrix of appropriate lower-noise materials and treatments. The QPTF established key requirements of the demonstration projects and engaged VDOT districts and contractors to identify suitable locations. The QPTF developed the material and construction specifications and helped assemble the contract documents that were used to advertise and award for construction. Finally, the Task Force worked with researchers to review the results from the performance monitoring and helped to frame the recommendations for continued use of these technologies in Virginia.

Selection of Technologies

The QPTF selected three asphalt surface materials and two mechanically applied finishes to concrete pavement as candidate QP technologies for the 2011 demonstration projects. Early test results from the 2011 demonstrations helped researchers identify candidate technologies for additional pilot projects in 2012. Preliminary findings were also instrumental in the selection of the technologies that were sent to NCAT for accelerated trafficking. Since none of the materials and treatments from 2011 exhibited significant distress or essential functional problems (such as low winter skid resistance) in the first year, tire-pavement noise performance served as the key discriminator for determining which technologies to pursue in the second season.

Demonstration Projects

The original matrix of candidate QP technologies was used in five demonstration projects. These projects consisted of three new asphalt projects and modifications to two existing concrete patching projects. The asphalt projects are located on state primary routes near Leesburg, Williamsburg, and Chester. One of the concrete sections is near Richmond and the other on an Interstate highway in Virginia Beach. The two 2012 demonstration projects were modified asphalt projects, one near Chantilly and the other in Marshall. All of the projects were on divided highways with four or more lanes of high volume, higher-speed traffic.

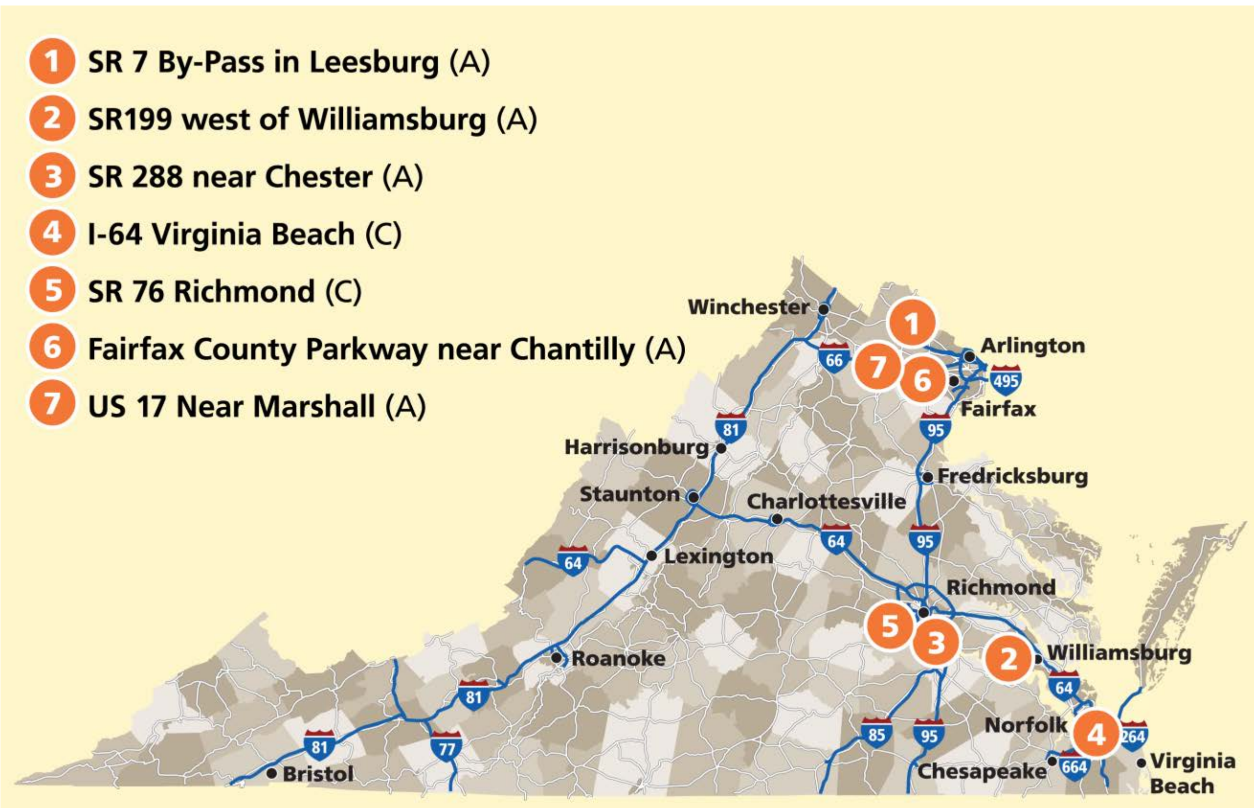


Figure 1. Locations for 2011 and 2012 Quiet Pavement Demonstration Projects. A = asphalt; C = concrete.

Accelerated Trafficking

Installation of the Virginia QP material on the NCAT test track was an attempt to see how these materials would respond to heavy vehicular traffic. Figure 2 is a plan view of the track. Two Virginia QP sections are located in the southwest corner of the track, and two sections along the north tangent (N3 and N4), as well as one section along the south tangent (S12). Those latter 3 sections incorporated a variation of the Virginia “asphalt control” surface and will be represented in comparison data.

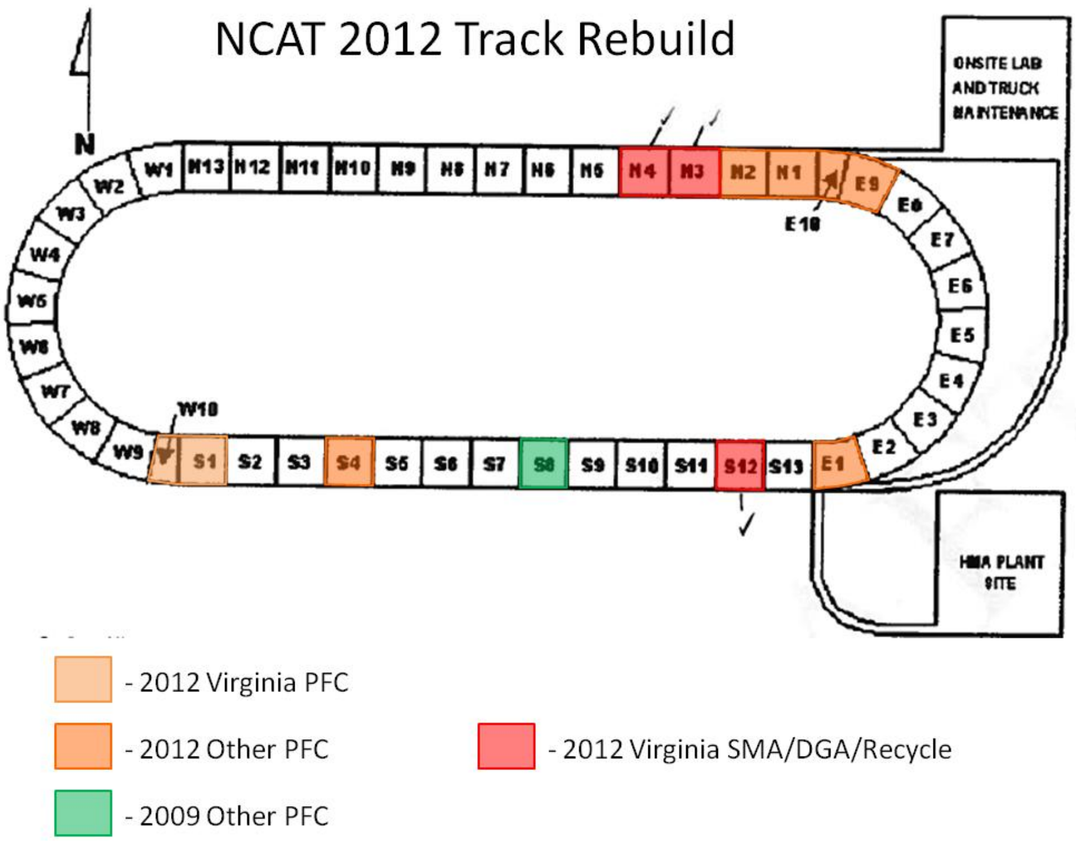


Figure 2. Virginia Quiet Pavement Technologies on 2012 NCAT Pavement Test Track. NCAT = National Center for Asphalt Technology; PFC = porous friction course; SMA = stone matrix asphalt; DGA = dense-graded asphalt

Functional Evaluation

Evaluation of the demonstration materials has focused on tire-pavement noise performance. Although noise performance has primarily been monitored using the On-Board Sound Intensity (OBSI) method, an initial series of modified “Community Wayside” tests were also performed immediately before and after the QP technologies were installed in 2011. The tire-pavement noise analysis includes an exercise that uses the relationship between OBSI and wayside noise data when the materials were new to estimate in-service wayside conditions.

To ensure that good noise performance did not come at the expense of safety, comfort, and overall functional durability, regular secondary tests monitored skid resistance, and ride quality. A complete description of each test method is included in the first interim report (*1*).

Material and Treatment Condition Review

Even the most functionally advanced wearing surfaces may not be cost-effective if the materials and/or treatments are not durable under Virginia traffic and climate. The spring 2015 review of Virginia's quiet pavement projects therefore includes an assessment of the general material and/or condition following 3 and 4 years of service for the 2012 and 2011 demonstration projects, respectively.

FINDINGS

Costs and Quantities

Table 1 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, are "incremental" costs attributed solely to the QP technology, are costs over and above costs of installing non-QP asphalt or concrete pavement, 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. Annualized cost figures will depend on reliable estimates of service life but at this point there is insufficient experience with the QP technologies to perform such estimates.

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	Per Mile (two 12-ft lanes)	Tons	Square Yards
PFC 9.5RM	125.81	5.77	$81,242	7,553	164,930
PFC 9.5	116.00	5.32	$74,906	10,394	228,020
PFC 12.5RM	128.00	12.80	$180,224	4,341	43,410
PFC 12.5	110.33	10.11	$142,349	12,082	131,833
CDG	N/A	6.86	$96,589	N/A	80,861
NGCS	N/A	10.84	$152,627	N/A	42,434

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

When considering these costs, it is important to remember that all the PFC materials need to be "day-lighted", which means they cannot abut an impermeable material (e.g., dense-graded asphalt). The materials that can be placed at 1-inch thickness (PFC 9.5 and PFC 9.5RM) can stop beyond the edge stripe with a 1-inch taper to the shoulder material. However, the PFC materials that are used at 2-inch application rates (PFC 12.5 and PFC 12.5RM) must extend through the shoulder. The associated added cost will depend on the width of the paved shoulder, but can be significant.

Other costs that are valuable for context include that of the top structural layer, a cost that can only be avoided when the existing pavement structure is already structurally sufficient. The top structural layer in these projects, also serving as the "control" surface, is stone matrix asphalt (SMA 9.5) placed at 1.5 inches in thickness. The average SMA 9.5 placed in 2014 cost about $8.60 per square yard or $121,500 per mile (two 12-ft lanes). Engineers typically anticipate plain finished concrete to cost about $50 per square yard or $700,000 per mile (*3*).

The last context-relevant cost is that for sound barriers. In 2013 and 2014, VDOT paid between $30 and $48 a square foot for "sound barrier" (VDOT's Top Standard Items report). Assuming these barriers are from 8 to 16 feet in height, the cost per mile (one side only) can range from $1.25 to $4 million.

Functional Evaluation

Tire-Pavement Noise

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. Finally, traffic noise measurements are usually filtered for reporting using a weighting scheme that places more emphasis on frequencies to which people are most sensitive. For highway traffic noise the A-weighted scale is used and it is indicated by adding an "A" designation to the index – e.g., 10 dB(A). More detail on the basics of sound, noise, measurement, filtering, and reporting can be found in the "Little Book of Quieter Pavements" (*4*).

Demonstration Projects

Modified community wayside tests were thoroughly described in the first interim report (*1*). However, for easy reference the results are included again here as Table 2. It should be noted that Table 2 provides noise measurements that were obtained shortly after installation / application of the associated QP technology. As *new* surface materials or treatments, the most effective technology achieved as much as a 10 dB(A) reduction in wayside noise as compared to the original surface (transversely tined concrete). In one case, the Route 7 project near Leesburg, the lowest-noise QP surface was 7.5 dB(A) quieter than the control surface (SMA 9.5). There are several important qualifications concerning these results:

- They reflect newest (and quietest) condition for each of the QP technologies. Subsequent testing has confirmed an increase in tire-pavement noise with age for all technologies (see Figure 1).
- It should be noted that the 10 dB(A) before-after difference associated with Route 288 was measured when one of the loudest highway surfaces (transversely tined concrete) was covered with porous asphalt. While that difference is significant, it represents less than a 5 dB(A) advantage when compared to the asphalt control material as used on the same project.

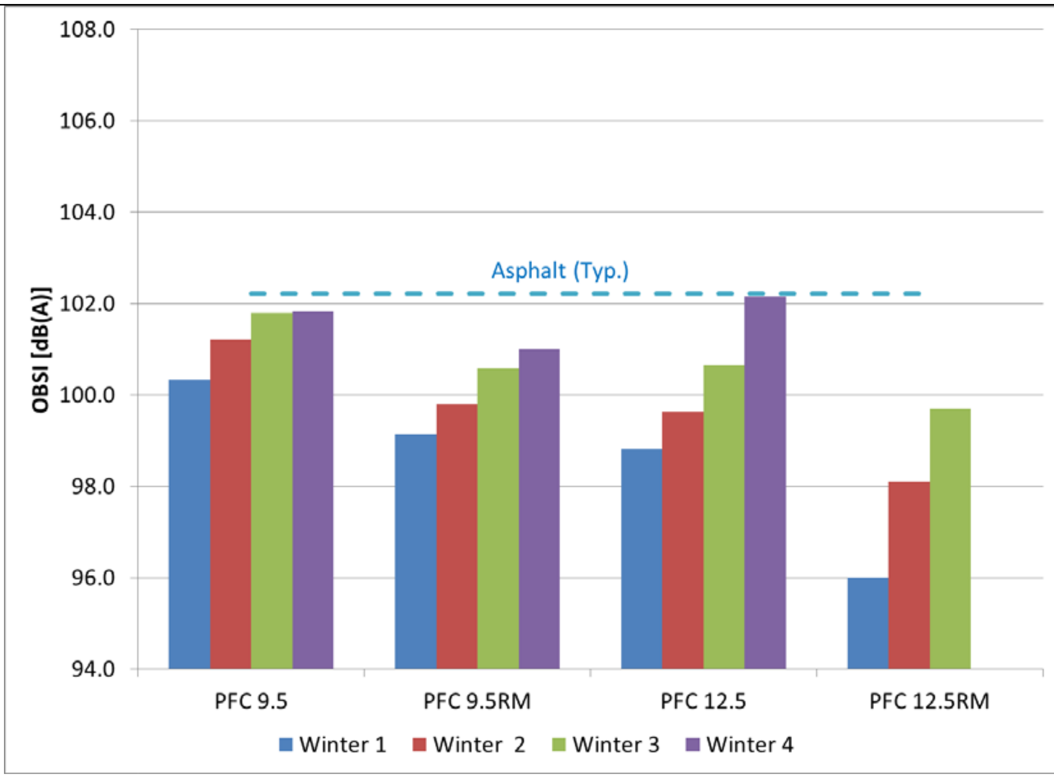
- The largest QP-to-control-surface advantage was measured where the control surface was actually louder than the original pavement (not typical).

Table 2. Normalized Short-Term Wayside Noise Measurements (*1*).

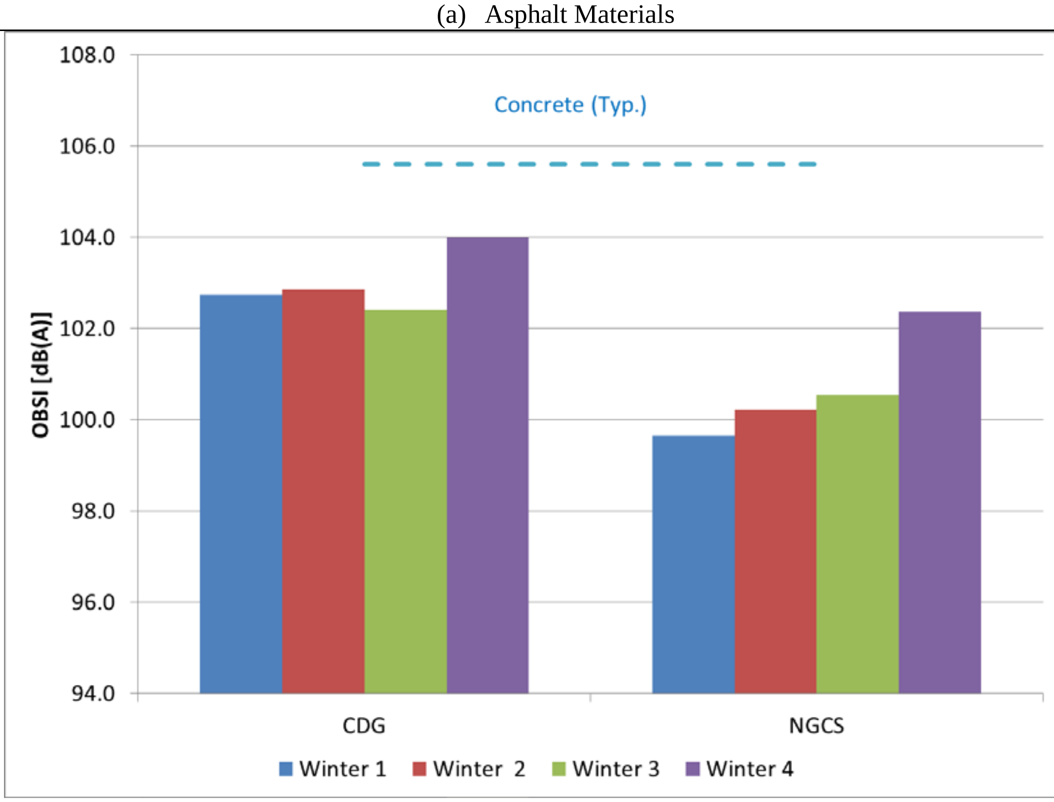
VDOT District	Roadway	Pavement Description	Date	Adjusted Leq (dBA)	After-Before Difference	Quiet Pavement Control Difference (dBA)
Northern Virginia	Route 7	SMA 9.5 (control)	6/28/11 12/8/11	71.2 73.8	2.6	- -
		PFC 9.5RM	6/28/11 12/8/11	73.9 73.8	-0.1	-2.7
		PFC 9.5	6/28/11 12/8/11	72.4 72.2	-0.2	-2.8
		PFC 12.5	6/28/11 12/8/11	72.9 68.0	-4.9	-7.5
Richmond	Route 288	PFC 9.5RM	7/6/11 12/2/11	79.2 68.7	-10.5	-4.6
		PFC 9.5	7/6/11 12/2/11	78.2 69.7	-8.5	-2.6
		PFC 12.5	7/6/11 12/2/11	77.3 67.2	-10.1	-4.1
		SMA 9.5 (control)	7/6/11 12/2/11	77.3 71.3	-5.9	- -
Hampton Roads	Route 199	PFC 9.5RM	6/30/11 12/1/11	70.4 65.7	-4.7	-3.2
		PFC 9.5	6/30/11 12/1/11	72.1 66.7	-5.4	-3.9
		PFC 12.5	6/30/11 12/1/11	73.8 68.1	-5.7	-4.2
		SMA 9.5 (control)	6/30/11 12/1/11	73.5 72.0	-1.5	- -
Hampton Roads	I-64	NGCS	6/29/11 12/9/11	80.9 77.0	-3.9	
		CDG	6/29/11 12/9/11	81.2 79.0	-2.2	

Note: if not designated a "(control)", the pavement is considered a QP technology. The June/July dates represent testing before the QP installation. The December dates reflect test results on the new technologies/treatments.

Wayside measurements can be affected by any site characteristic (topography, shoulder type, etc.) that varies between the tire-pavement interaction and the receptor. For that reason the OBSI system was used to better isolate the influence of the pavement surface on the total noise picture. Figure 3 summarizes the noise-monitoring testing as conducted with the OBSI system (*5*). It also illustrates the change in tire-pavement noise after each successive winter. The rubber modified PFC12.5 placed at 2 inches was the lowest-noise pavement when in new condition and remains so after 3 winters. However, given the increasing noise levels associated with this pavement, it is on a trajectory to match the noise levels of the typical asphalt surface within the next two years. After the fourth winter the coarsest of the 3 other asphalt technologies, the non-rubber-modified PFC 12.5, is indistinguishable from a typical asphalt surface, while the finer rubber-modified PFC is making the slowest gains in total tire-pavement noise.



(a) Asphalt Materials



(b) Concrete Treatments

Figure 3. Quiet Pavement Technologies - Acoustic Longevity.

Structural failures unrelated to the QP technology prevented representative testing in one direction of the concrete project on Route 76 (see later discussion on “Observed Condition of Materials”). The most recent OBSI measurements from the remaining quiet concrete sections indicated higher average tire-pavement noise levels. However, the NGCS remains considerably quieter than a typical transversely tined concrete surface.

While the OBSI system is better suited for isolating the noise contributions from the pavement surface, the “wayside” and beyond is where the receptors live, work, and recreate. For that reason it is helpful to attempt some extrapolation from the OBSI readings. Fortunately, recent related work through the National Cooperative Highway Research program (NCHRP) developed some offsets that can be used to estimate the wayside noise levels from OBSI test results (*6*). For most normal high-speed traffic streams, the wayside can be approximated from OBSI data using the offsets that are shown in Table 3.

Table 3. Offsets for Predicting Wayside from OBSI.

Application	Offsets (to be subtracted from OBSI level), dB	Site Average Standard Deviation, dB
Light Vehicles @ 25 ft	21.8	1.3
Heavy Trucks @ 25 ft	12.9	1.4
Light Vehicles @ 50 ft	28.3	2.1
Heavy Trucks @ 50 ft	19.2	1.8

Adapted from NCHRP Report 630 (*6*).

Table 4 reports the average OBSI values for the new treatments, along with the corresponding estimated wayside values (using “light vehicles at 50 ft” from Table 3), and then a comparison of each QP strategy to the relevant control (the shaded rows). Table 4 also shows the most recent average in-service OBSI reading for each strategy, a corresponding estimated wayside reading, and another comparison to the respective control surfaces. While individual corrections are shown for each surface (as available) for the new-treatment data, the corrections applied to the in-service data is simply an average of that observed for either all the asphalt or all the concrete projects. Specifically, the corrected wayside for asphalt projects is assumed to be 2.6 dB(A) lower than the Table 3 estimate, while the concrete readings are assumed to be 4.2 dB(A) louder.

Table 4. Wayside Noise as Estimated from Average OBSI Data.

Pavement Description	New Treatment Noise dB(A) OBSI	Wayside Estimated[a]	QP vs. Control	In-Service Noise dB(A) OBSI	Wayside Estimated[a]	QP vs. Control
PFC 9.5	100.9	72.6	**-1.7**	102.3	74.0	**-0.7**
PFC 9.5RM	99.8	71.5	**-2.8**	102.0	73.7	**-1.0**
PFC 12.5	99.3	71.0	**-3.2**	102.1	73.8	**-0.9**
PFC 12.5RM[b]	95.9	67.6	**-6.6**	99.7	71.4	**-3.3**
SMA 9.5	102.5	74.2	**0.0**	103.0	74.7	**0.0**
NGCS	100.6	72.3	**-4.8**	103.4	75.1	**-2.0**
CDG	103.6	75.3	**-1.8**	103.9	75.6	**-1.4**
TT Concrete	105.4	77.1	**0.0**	105.4	77.1	**0.0**

[a] Estimated using offset from Table 3 that assumes "light vehicle" traffic @ 50 feet.
[b] The PFC 12.RM materials have only experienced 3 winters of service at this time

Consistent with the results shown in Figure 3(a), the PFC 12.5RM is estimated to have provided the most significant reduction in wayside noise when newly placed. After 3 winters in-service, it maintains an estimated *noticeable* advantage over the average asphalt control. None of the other surfaces, all of which have experienced an additional winter in-service, have noise advantages that most people would notice.

Accelerated Trafficking (NCAT Test Sections)

The Virginia QP sections on the NCAT test track were tested regularly with an OBSI system. The emphasis on the test track was traffic loadings (not winter maintenance) so tire-pavement noise characteristics were monitored for change with cumulative 18,000 pound equivalent single axle loadings (ESALS). Similar testing was conducted on the more conventional surfaces that capped the 3 other Virginia test sections on the test track.

Figure 2 (presented earlier) shows the location for each section on the track and Figure 4 presents the OBSI data. As compared to the measurements made on the Virginia Demonstration projects, the NCAT noise levels are routinely lower by 2 dB(A). The PFC 12.5RM was the lowest-noise surface, while the SMA surfaces were approximately 4 dB(A) higher. Any advantage from rubber modification was quickly lost under heavy traffic. After 10 Million equivalent single axle loadings (ESALs) the PFC 12.5 had the lowest-noise levels of the 5 Virginia surfaces at the track. However, none of the differences between respective surfaces were significant enough for humans to detect.

The Virginia paving materials otherwise performed very well under the heavy loading at the test track. Rutting performance was excellent and there were no indications of imminent failure for either the QP materials or the more conventional wearing-course materials.

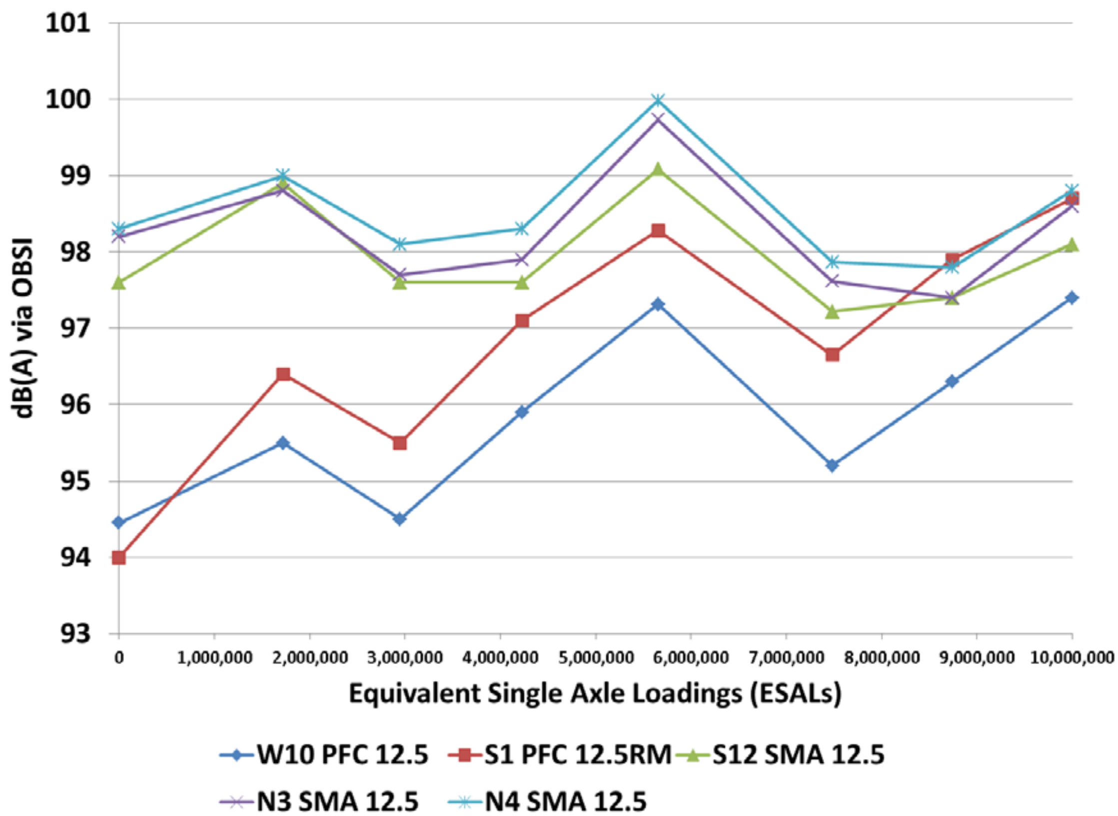


Figure 4. Virginia Quiet Pavement Technologies at NCAT Test Track - Acoustic Longevity under Heavy Traffic.

Resistance to Skidding

Figure 5 compares the new-surface skid resistance to the last in-service measurement on the QP and control surfaces. Tire-pavement friction remains high and even slightly improved for most materials/treatments. The Grip Numbers on the PFC materials are particularly impressive, as are those for transversely tined concrete and the conventional diamond grind (CDG) surface.

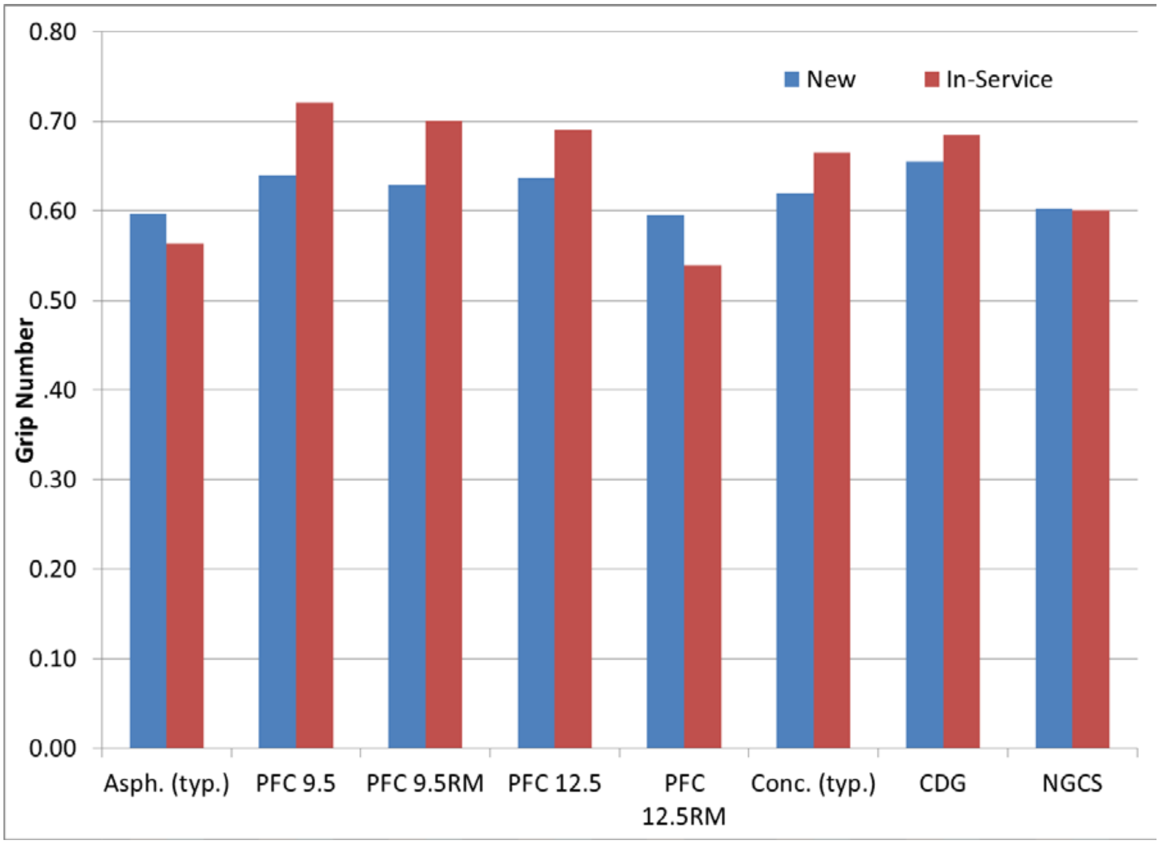


Figure 5. Quiet Pavement Technologies – Skid Resistance.
Measured with GripTester device (ASTM – E2340).
In-service tests were after 3 to 4 winters under traffic.

Ride Quality

Figure 6 summarizes the overall average ride quality for the quiet pavement treatments and the respective control surfaces. Ride quality is measured using the International Roughness Index (IRI), an index for which lower numbers are better. Note that since there were no new concrete control surfaces, "conc. (typ.)" represents data for in-service segments that were adjacent to the NGCS. The CDG value also represents in-service adjacent pavement. For the newly installed materials and treatments, the "in-service" averages reflect ride quality after 4 winters for everything but the PFC 12.5RM, which was tested for only 3 winters.

The quiet asphalt treatments have, on average, changed very little in the three and a half to four years that are covered by this evaluation. The average for the asphalt control surfaces [Asph.(typ.)] has increased some, but that is due exclusively to a dramatic increase in roughness on one of the four short sections of SMA on the Route 288 project. The substantial increase in roughness for the NGCS treatment is likewise explained by material and/or structural failures on the Route 76 project. The IRI values for the I64 NGCS remain very low – approximately 30in/mi.

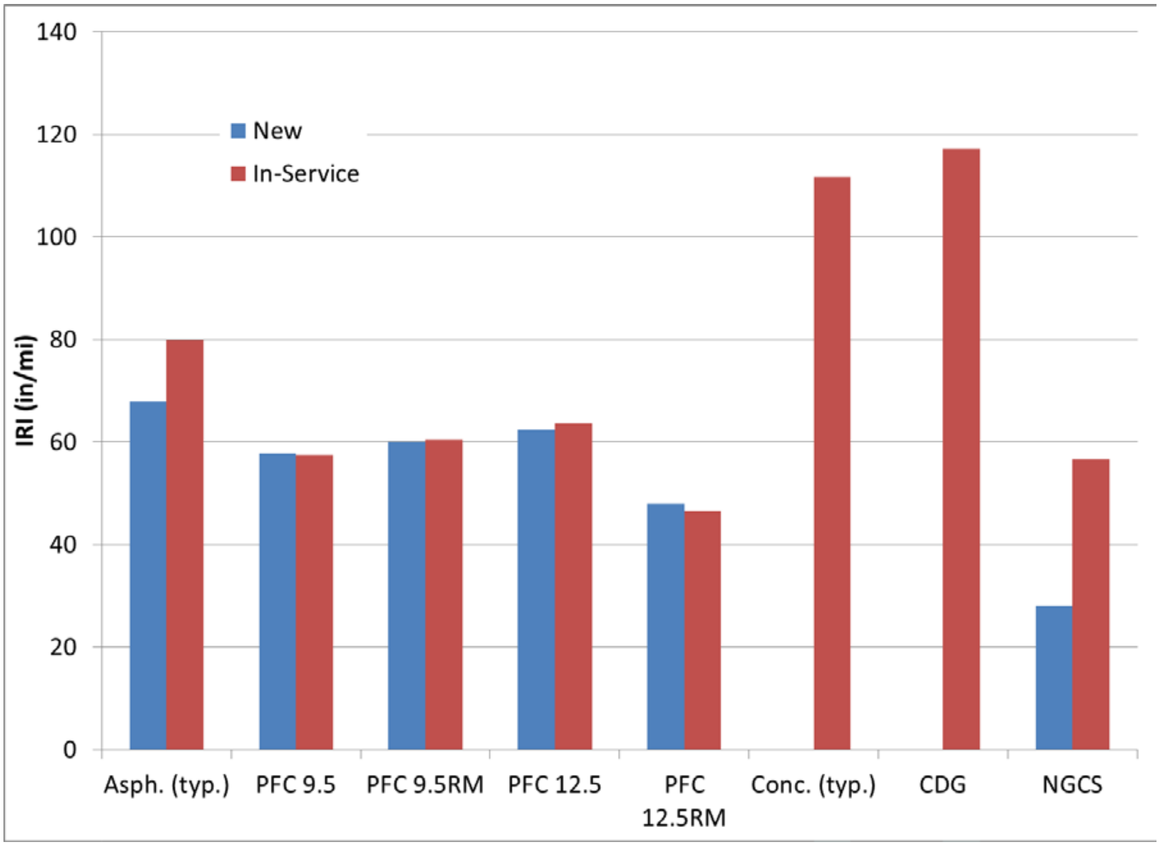


Figure 6. Quiet Pavement Technologies – Ride Quality.
Note that although the in-serve values for the concrete control and CDG do represent pavement adjacent to the quiet pavement trials, they do not reflect what is achievable with a newly placed or ground concrete surface.

Winter Performance

2011/2012

Winter 2011/2012 should have provided the first opportunity to gain experience with the interaction of QP surfaces and Virginia's winter weather. Unfortunately, according to the National Oceanic and Atmospheric Administration*(7)*, the three month period starting December 2011 was the fourth warmest winter since records have been kept (starting in 1895). As a result, little in the way of frozen or freezing precipitation actually fell on the QP demonstration projects and there was correspondingly little feedback from the local crews with responsibility for winter maintenance. Crews near Leesburg experienced one of the only significant snow events in late October 2011. In email correspondence from the nearby residency (November 14, 2011), "more visible" freezing material was noted on the QP sections as distinguished from the typical pavement surfaces. Most importantly, as of late spring 2012 there had been no reports of an actual or perceived compromise of safety that could be attributed to the interaction of freezing weather and QP technologies.

2012/2013

Although cooler than the previous winter, Winter 2012/13 was still the 18th warmest on record (*7*) 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 rapidly (i.e., “freeze” earlier) and maintenance crews addressed this with slightly earlier and additional applications of deicing chemicals.

2013/2014

Winter 2013/14 brought with it some of the first significant wintry precipitation. It likewise provided the first significant operational experiences with addressing frozen (and freezing) precipitation over the quiet pavement technologies. The northern-most project (Route 7 Loudon County) provided the most challenge, as local maintenance crews reported on one occasion that even after repeated application (7 times) of straight salt and brine mix, the surface was “still frozen and multiple vehicles were in the ditches” (email correspondence January 5, 2014). In addition to being the northern-most installation, the Route 7 project also has the steepest grades and the most severe curvature. The other quiet pavement project in NOVA (Fairfax County Parkway) exhibited the earlier freeze characteristics (see pictures in Figure 7), but maintenance crews were able to “keep up” and prevent any significant operational problems. There were no winter-maintenance-related problems reported from the demonstration projects in other parts of the state.

(a) Asphalt Control

(b) Quiet Asphalt

Figure 7. Contrast in Winter "Freeze" Characteristics.
Photos taken within minutes – quiet asphalt section (b) immediately precedes asphalt control (a).

2014/2015

Winter 2014/15 started out cold and dry, but ended with a "flurry" of wintry events. The porous surfaces at the Route 7 project interacted with winter weather much as they had the previous winter. The ongoing west-bound construction served to further exacerbate some developing material durability issues. Aggressive winter maintenance (plowing) combined with marker eradication activities to accelerate raveling of the thin porous materials at the western end of the project. Even the materials that remained largely intact had experienced considerable scarring and gouging from the winter maintenance activities. The most remarkable winter experience of the 2014/15 season involved the PFC section on the Fairfax County Parkway. During at least one winter event officials were forced to close the facility due to the inability of crews to keep up with deicing needs on the short section of porous material (phone correspondence with Transportation Operations Manager/NCR Watch Desk SPOT Report #003-20150301). According to the Assistant District Administrator for Maintenance, the benefits of the eight months of improved wet-weather performance are definitely outweighed by the approximately four month period in which wet-freezing precipitation could demand added maintenance attention and a potential freezing hazard.

Winter maintenance on the Route 288 project near Richmond is handled through a contract. The crew supervisor for the contractor, from Interstate Maintenance North, was very helpful in describing the interaction of Virginia winter and the Richmond PFC surfaces. He described in detail the added attention that was required to effectively maintain a separation of frozen precipitation and the pavement surface. Several late winter events had been particularly challenging, but the experience enabled crews to fine-tune an aggressive treatment that involved early and heavy application of magnesium chloride, which improves melting at much lower temperatures. The approach is more expensive, but also more effective. VDOT's Assistant District Administrator for Maintenance (ADAM) concurred with the contractor when discussing the approach to safely maintain PFC surfaces during winter events. While acknowledging the added attention and expense associated with winter weather, the ADAM was quick to also suggest that improved wet-weather visibility may well have prevented accidents. Although subjective, he also pointed out the marginal improvement in quality-of-life for the facility neighbors who had benefited from reduced traffic noise. The reader should know that the Route 288 project also provided an overlay for a badly distressed (and rough) concrete pavement. The contractor participating in the discussion of the Route 288 project went on to provide a rationale for maintaining more, not less, PFC material. Longer stretches of uniform surface materials, especially when fundamental properties affect maintenance requirements, is much preferred to "spot" applications. When one plow/deicing unit is covering 10 miles of highway, it is much simpler for that unit to apply one strategy (with one chemical package). Consistency of surface type and condition is also safer for the traveling public.

The Route 199 project in Williamsburg was clearly performing best of the quiet asphalt treatments. Correspondence with the operations manager of the Williamsburg Residency indicated that winter maintenance was going as expected with the PFCs. Aggressive use of chemical deicers in combination with a milder climate led to reduced need for aggressive plowing. The noticeable absence of plow-induced gouging confirmed the comparatively amiable interaction of winter and quiet asphalt materials in Williamsburg. The Assistant District Administrator for Maintenance agreed that the local maintenance crews had done an excellent job of staying on top of the Route 199 PFC materials. He did emphasize, however, that the presence of these special materials do draw significant resources during the events that always exert the most stress on the Department's resources. Despite the District's (and Residency's) exemplary performance, this ADAM was understandably skeptical as to whether the added benefits were worth the added risks that are associated with winter performance.

Observed Condition of Materials

Quiet Asphalt Materials

The quiet pavement demonstration projects were visited in late March 2015 to conduct a visual assessment of material condition. As mentioned under discussion of "Winter Performance", the thinner PFC materials near the western end of the Route 7 quiet pavement demonstration near Leesburg were experiencing the most serious material distress. The west bound materials are also experiencing the damaging effects of heavy construction traffic as part of a widening project for a truck climbing lane. In addition to frequent trafficking with heavy equipment, temporary striping and eradication activities have applied added stress to the thin open-graded materials, which has resulted in complete loss of material in several places (Figure 8). The rubberized asphalt (AR-PFC 9.5) in the east bound direction has raveled out and been patched at the very beginning of the project, indicative of a "cold start" at the beginning of the paving activities (Figure 9). Also very common in the eastern end of the project were missing snow-plowable raised pavement markers (SRPM). The thicker PFC materials (PFC-12.5) on the eastern end of the project were performing much better as a material. However, plow-induced gouging was very common throughout the project, especially along the centerline just beyond each of the remaining SRPM's.

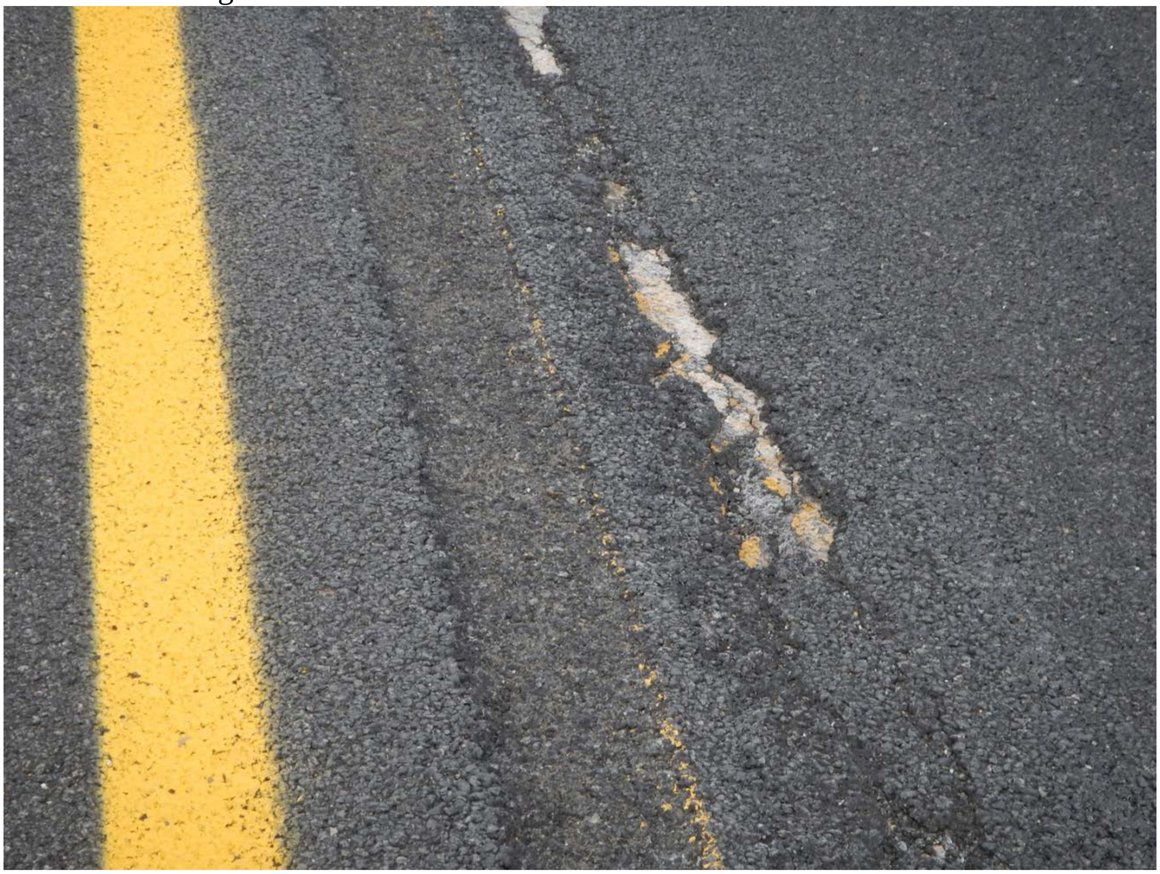


Figure 8. Distress in PFC Triggered by Line Eradication Activities.

Figure 9. PFC Failure Due to "Cold Start"- Route 7.

The rubber-modified PFC material on the Fairfax County Parkway (Route 286) was in better condition than the Route 7 materials. It is also one year newer. The post-SRPM gouge pattern was present, but with less severity. There were also several missing markers, especially in the north bound direction. Accumulation of fine aggregate and sand along the shoulders of the PFC materials implied fairly extreme recent winter maintenance measures (sanding is not routine on primary and Interstate system roadways). The SMA control section that is adjacent to the PFC was in excellent condition. The complete absence of plow gouging or missing SRPMs on the SMA section was notable.

The PFC materials on Route 288 near Richmond were intact, but were among the most oxidized in appearance of all the demonstration materials. The PFC 12.5 was visibly coarser, and likewise the most oxidized. There was some spot patching noted in the southbound direction and some very obvious raveling in the northbound lanes. Much like the PFC 9.5RM material near Leesburg, the localized but premature raveling appeared related to a “cold start” (Figure 10). The PFC 9.5RM also appeared prematurely “dry”. The best “looking” material on Route 288 was the non-rubberized PFC 9.5.

Figure 10. More Evidence of "Cold Start" in PFC - Route 288.

The quiet pavement materials on Route 199 near Williamsburg were in excellent shape. A light rain was falling during the visit and the reduction in splash and spray was dramatic. Unlike any of the other PFC materials in the state, there was no plow-induced gouging evident on any of the Williamsburg materials. The joint that identifies the material change from PFC 9.5RM to PFC-9.5 was obvious, but the transition from PFC 9.5 to PFC 12.5 was visually undetectable in either direction. There was one suspected “cold joint” in the passing lane of the south-bound PFC 9.5 materials, but no other material durability concerns.

In addition to the quiet pavement treatments that were installed in 2011 and 2012, the March 2015 review included a visit to an earlier PFC that had been placed on Route 234 near Manassas in 2008. Many aspects of that material, including early-age functional performance, were documented in a previous report (*20*). Predating the formal quiet pavement demonstration projects, the Route 234 material serves as VDOT’s oldest in-service porous friction course. Despite its age (almost 7 years), it remains in good condition with plow-induced gouging making up the most pervasive distress. There is one pothole at the beginning of the southbound passing lane and several missing SRPMs throughout, but no routine cracking of any type. There is a dense-graded surface mix placed immediately adjacent to the PFC by the same contractor in the same year. Although a half-inch thicker, the dense-grade material already exhibits typical environmental block cracking, along with some longitudinal wheel-path cracking.

Quiet Concrete Treatments

While the quiet asphalt technologies involved design, production, and placement of new materials, the quiet concrete technologies were limited to treatment of existing in-place materials. Unfortunately, in one case the materials that were “treated” have failed in large enough quantities to impact the relevance of the demonstration project (see Figure 11). Route 76 near Richmond has fared particularly poorly and as of spring 2015 there was no longer sufficient continuous experimental surface to permit a representative noise test. The I64 project in Chesapeake (jointed concrete) remains in good condition.

Figure 11. New Concrete Repair in Quiet Concrete Project - Route 76.
The darker material to the left is NGCS. The patch to the right has been transversely tined.   Note date on new patch (3-17-2015).

Related Policy and Research

Policy and Regulation

The Code of Federal Regulations (23 CFR Part 772), in section 772.13 on Analysis of Noise Abatement, provides that each highway agency must develop *feasibility* and *reasonableness* criteria. The feasibility of an abatement measure is further defined as achieving at least a 5 dB(A) highway traffic noise reduction at impacted receptors. The highway agency then needs to define, and receive FHWA approval for, the number of receptors that must benefit from this reduction. To satisfy the reasonableness requirement, the abatement strategy will be seeking a noise reduction design goal. The CFR requires the highway agency to define (with FHWA approval) a design goal of between 7 and 10 dB(A) of reduction, and then go on to define the number of benefited receptors for whom the design goal is realized.

Pursuant to federal regulation (23 CFR, Part 772) the Commonwealth Transportation Board adopted Virginia's State Noise Abatement Policy (SNAP) and pursuant to that policy, all transportation improvement projects, that meet the federal definition of a Type I project, developed in conformance with the Virginia Department of Transportation's guidelines must be in conformance with those federal highway traffic noise impact analysis and abatement procedures and guidance mandated by FHWA.

Virginia's current state noise abatement policy (SNAP) and related guidelines were approved by the FHWA on March 15, 2011 and then approved by the Commonwealth Transportation Board on June 15, 2011. The feasibility factor established in VDOT guidelines developed pursuant to the SNAP and federal regulations requires that at least fifty percent of the impacted receptors (66 dB(A) or greater) receive a 5 dB(A) or more of insertion loss (reduced noise) through the abatement strategy. Under the guidelines, VDOT's design goal (for *reasonableness*) is 7 dB(A) of insertion loss for at least one impacted receptor.

It is also noted, pursuant to federal regulation only those noise abatement measures set forth in 23 CFR 772.15 (c) are eligible for federal funding and QP technologies are not listed as eligible noise abatement measures. Further, according to FHWA's Memorandum entitled Guidance on Quiet Pavement Pilot Programs and Tire/Pavement Noise Research (http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/qpppmem.cfm), FHWA policy restricts making adjustments for pavement type in the prediction of highway traffic noise levels and using specific pavement types or surface textures as noise abatement measures. In order for FHWA to determine whether Quiet Pavement related changes to a State DOT's FHWA-approved noise policy are warranted, the State DOT is required to either: develop and obtain FHWA approval for a Quiet Pavement Pilot Program (QPPP) in the State; or conduct Quiet Pavement research that is reviewed and approved by FHWA.

If a State wishes to develop a QPPP, according to FHWA's Guidance Memorandum, "the program should include a Program Plan and a Data Acquisition Plan, which should be reviewed and approved by the respective FHWA Division Office with the concurrence of the Office of Natural and Human Environment (HEPN)." The Program Plan will be specific to that State DOT(s) and should address, at a minimum, certain items such as noise characteristics, safety, and

durability factors over time. The FHWA guidance provides a Sample Data Acquisition Plan that should be used as a proto-type for data collection; however, a State DOT's QPPP may add items to adequately document the safety, durability, and noise requirements of their program. A State DOT that adopts at a minimum the nine items in the DOT Program Plan and the Sample Data Acquisition Plan utilized by Arizona for its QPPP will obtain concurrence from FHWA. For any project in a QPPP, a State DOT(s) is allowed to make adjustments for pavement type in the prediction of highway traffic noise levels and/or use specific pavement types or surface textures as noise abatement measures. However, **a commitment must also be made to maintain in perpetuity any noise reduction attributed to the pavement type or surface texture**."
Essentially the QPPP must:

- Account for documented noise reduction benefits of pavement types by adjusting predicted (modeled) highway traffic noise levels in project noise analyses (this may either reduce the number of identified traffic noise impacts or reduce the height of noise barriers that are required to mitigate identified traffic noise impacts);
- Include post-construction monitoring for the projects to collect acoustic, texture, and frictional characteristics **(monitoring will be performed for at least 5-10 years)**;
- Document the general public's reaction to the noise reduction capabilities of specific pavement types; and
- Include commitments to take appropriate actions to provide required noise reduction into perpetuity.

State DOT(s) may also elect to conduct "quiet pavement" research**.** Once completed, this research would help substantiate a possible future policy change in its program to allow the use of a pavement adjustment factor in traffic noise predictions and the use of pavement types or surface textures as noise abatement measures. To conduct "quiet pavement" research, a State DOT(s) should develop a Quiet Pavement Research Plan that (1) outlines its intended purpose, (2) details all data acquisition, and (3) contains periodic reporting requirements. The Research Plan should be reviewed and approved by FHWA. The Sample Data Acquisition Plan (http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/qpppdataplan.cfm) should be used as guidance for data acquisition. Noise data must be gathered to document the noise levels in residents' backyards (wayside acoustical data). The research should include, for each applicable pavement type, a minimum of four studies that substantiate the policy change being considered. To account for variations in pavement design, construction, maintenance, and materials, these studies should:

- be in different locations within the State;
- collect noise characteristics and safety and durability data for at least 5-10 years (or longer, based on the pavement life); and
- involve different construction contractors.

If any pavement that is constructed in the QPPP and/or "quiet pavement" research fails to meet structural requirements to the extent that road users' safety is compromised, the State DOT(s) must immediately take action to achieve acceptable safety levels by repaving with an adjusted pavement mix, or repaving with a documented safe pavement type or surface. FHWA must concur with the proposed remedial action.

According to the Guidance Memorandum "the FHWA policy does not allow the use of pavement type or surface texture as a noise abatement measure. If a policy change is to occur, results of the QPPP and/or additional research must demonstrate the safety and durability of each 'quiet pavement,' as well as its noise reduction capability. The safety and noise reduction of the pavement must last in perpetuity."

Research in Other States

A number of state agencies have conducted quieter pavement research, but few have formally recognized materials or treatments specifically for use to reduce traffic noise. Only one state has received official FHWA approval to accept pavement type as a noise mitigation strategy, but only under a unique set of circumstances. Others have documented predictable differences among typical roadway surface types and offer recommended strategies when traditional methods (like barriers) are not feasible. Finally, others reference an unacceptable combination of inadequate material and functional durability to recommend against use of these materials for any application.

Arizona

The Arizona Department of Transportation (ADOT) first recognized the noise reducing characteristics of some pavement types in the early 1990s. By the late 1990s ADOT was using an asphalt rubber friction course (ARFC) to overlay transversely tined concrete and reducing wayside noise by 4 to 5 dBs. Positive feedback from neighbors of those facilities led ADOT to develop a QPPP in 2002 (*8*), a program that sought approval to use ARFC as a noise mitigation strategy. This program was approved by the FHWA in 2003 and remains the only example to date in which a pavement type serves as a recognized noise mitigation strategy (*9*). It is noted that Arizona's agreement with FHWA allows them to potentially utilize lower heights for noise barriers along the freeway in combination with quiet pavement when designing for noise mitigation**.**

California

The California Department of Transportation (Caltrans) has also been studying quieter pavement since the 1990s with particular emphasis on changes in noise performance over time (*10,11*). While not participating in a QPPP, the FHWA recognized a quiet pavement research (QPR) plan for Caltrans in 2006. The QPR supported development of a Pavement Policy Bulletin that formally recommended pavement surface types that could be considered quieter strategies (*12*). These strategies were recommended for situations in which traditional barriers were not existing or infeasible, but were not accepted in lieu of barriers.

Washington

Washington State Department of Transportation (WSDOT) has a research program that predates Virginia's, but is otherwise similar in scope. WSDOT has experimented with rubber modified and conventional PFC materials for reduced noise. WSDOT's research was also concerned with the longevity of reduced noise characteristics, as well as material performance under severe winter weather and aggressive winter maintenance (*13*). Their research supported a recommendation against using the PFC materials for two reasons. Where winter weather was severe, studded tire and chain use caused rapid material deterioration. In parts of the state where the winter was less severe, WSDOT was disappointed at the short duration of noise mitigation properties.

WSDOT also experimented with several texturing techniques to reduce noise of concrete surfaces, including the Next Generation Concrete Surface (NGCS). Unfortunately, wear on pavements from studded tires also accelerated surface wear on the experimental concrete textures and increased tire-pavement noise (*14*).

National Program Research

The most directly relevant and recently-completed national research activity was the NCHRP project 10-76, Evaluating Pavement Strategies and Barriers for Noise Mitigation (*15*). This research was designed to develop a rational cost-comparison methodology to incorporate the noise-relevant characteristics of pavement surfaces with barriers for mitigating highway noise. It establishes a way to incorporate OBSI data into the FHWA Traffic Noise Model (FHWA TNM) to evaluate combinations of barriers and pavement strategies to predict the overall noise levels.

A useful chapter of the NCHRP report contained case studies that applied the developed methodology (*15*) to typical highway projects. Among the findings from those exercises that related particularly well to the Virginia demonstration program were:

- "A design goal criterion of 7 dB is generally not achievable with current quieter pavement alone…"
- "Maintaining the acoustic performance of quieter pavements can result in a significant increase in life-cycle cost."
- "In some instances, barriers do not meet criteria because of low receptor density or geometric factors, but the quieter pavement would provide noise-level reduction of 3 to 4 dB to impacted receptors at low enough cost."

Ongoing Activities

The Texas Transportation Institute (TTI) was awarded a FWHA contract in the fall of 2014 to focus on design, construction and maintenance of porous graded asphalt materials like those used in the Virginia projects (*FHWA Award Number DTFH61-14-C-00033*). There are no formal publications available from this research at this writing, but the researchers did conduct a series of presentations and interviews at the January 2015 Annual Meeting of the Transportation Research Board. A summary (*available from author*) of the interviews and discussion that followed the presentations provides some of the most up-to-date insight on both national and international experience with porous wearing course materials. "Key Points" from that summary include:

- Where used, perceived advantages of porous asphalt surfaces are safety and environmental benefits, including reduced splash and spray and noise reduction
- Some US state agencies will no longer use porous asphalt as a surface mix for the following reasons:
    - Vehicular crashes caused by "black icing" (Colorado)

    - Increased winter maintenance costs (New Jersey)
    - Low durability, clogging, and studded-tire induced damage (Oregon, Washington)
- Pretreatment with salt/brine solutions before onset of frozen precipitation is effective and may be necessary for porous asphalt that experiences frequent freezing precipitation
- Studded tires and aggressive snow plowing adversely affect durability
- Some durability problems related to production and construction issues, not material design.
- Europe (e.g., Sweden) continues to explore porous asphalt for noise abatement, but damage associated with winter use and maintenance remain a common problem

GENERAL DISCUSSION

The FHWA position on pavement strategies has not changed over the time-window of this research. Low-noise pavement treatments and materials have yet to be accepted as a routine mitigation tool for highway traffic noise. The exception coming only if a state proffers a Quiet Pavement Pilot Program, which requires that the state establish that it has achieved the required noise reduction (with pavement type as at least a component of that strategy). That state must then continue to monitor that pavement to ensure that the required overall noise reduction has been maintained and is obligated to restore the surface to the required state at any time during the project's life…in perpetuity.

In none of the Virginia demonstration projects were the QP technology observed to provide as much as 7 dB(A) advantage over the respective control surface in OBSI measurements. One of the quiet pavement technologies nearly achieved VDOT's design goal when it was new (Table 4), but its noise advantage had dropped to *just noticeable* (~3 dBs) after 3 winters in service. Researchers attribute much of the loss in noise-reducing function of PFC materials to pore clogging through winter maintenance practices (*16, 17, and 18*). However, the progressive increase in tire-pavement noise on the Virginia materials at the NCAT Test Track suggests that heavy traffic also has a substantial negative impact. In fact, the Virginia PFC materials on the Track (no winter maintenance) lost noise advantage over control surfaces more rapidly than did those on the Virginia demonstration projects (and subject to Virginia winters).

CONCLUSIONS

- Porous Friction Course (PFC) materials and lower-noise concrete finishes can be installed successfully. However, special consideration during design should be given:
    - Due to safety issues porous asphalt materials must be day-lighted (i.e., carried through shoulders) which increase the initial and long-term maintenance costs.
    - Materials must be placed on new pavement or on pavement in good structural condition, as these materials make no structural contribution.
- PFC materials provide beneficial spray reduction and improved skid resistance.
- QP materials and finishes exhibit excellent ride quality.

- PFC materials require special attention and treatment to avoid specific safety hazards during winter weather events. Close monitoring, as well as early and aggressive application of deicing chemicals are necessary.
- For asphalt technologies (PFC's) – Noise reduction levels are indistinguishable from asphalt control surface after 4 winters (less than 2 dB(A)).
- For concrete technologies (NGCS) – Noise reduction levels are noticeable (~4 dB) after 4 winters
- None of the QP technologies provided sufficient noise reduction to singularly satisfy federal regulations for noise abatement, nor do federal regulations and policy currently recognize QP technology as an appropriate noise abatement measure.
- There are incremental/additional costs associated with the initial installation of QP above and beyond the costs associated with similar pavement types. In addition, for the PFC technologies, additional costs attributable to specialized treatment can be expected in winter weather. While a responsible comparison of costs would entail a per-year-cost comparison, such comparisons will depend on reliable estimates of service life. At the present time, there is insufficient experience with the QP technologies to perform such estimates.

RECOMMENDATIONS

1. VDOT's Materials, Maintenance, and Research Divisions should further investigate the programmatic impact and viability of PFC materials where weather creates potential safety hazards or untenable demand on winter maintenance forces – consider restricting PFC use to eastern region of the state.
2. VDOT (Environmental, Materials, Maintenance, and Research Division) should continue to monitor federal law and policy with respect to the use of QP strategies as an accepted tool for mitigating noise and the eligibility of QP strategies for federal funding.
3. VDOT (Environmental, Materials, Maintenance, and Research Division) should continue to monitor national and international research and development for alternative measures/technologies that show promise for reducing and/or eliminating traditional sound barriers.
4. At the present time VDOT should not consider QP strategies as a replacement for noise barriers, as FHWA has yet to accept pavement type as a routine mitigation tool for highway traffic noise.

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APPENDIX A

§ 33.2-276. (Effective October 1, 2014) Noise abatement practices and technologies.

A. Whenever the 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, first 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. Vegetative screening, such as the planting of appropriate conifers, 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 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 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, 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.

C. The governing body of any locality, at its own expense, may evaluate noise from highways it may designate for analysis. Such evaluation shall be accepted and relied upon by the Department if such evaluation is prepared in accordance with and complies with applicable federal law, regulations, and requirements, as well as guidelines and policies issued by the Board, relating to noise abatement and evaluation. This provision shall not apply to projects for which the Department is required to perform a noise analysis.