By Tom Kuennen, Contributing Editor

Quiet Moves

A war is being waged on noise generated by pavements and highways.

Today, highway noise is considered an undesirable emission, just as if it were a noxious gas out of the tailpipe. But road designs can do much to attenuate highway noise.

These include active methods to quell noise created at the pavement-tire interface, such as variable transverse groove patterns on concrete and the new Next Generation Concrete Surface (NGCS), and thin and thick open-graded or porous asphalt friction courses.

But they also include passive methods, such as sound walls, vegetation screens, earth berms, recessed pavements, or combinations of the foregoing.

And even as the techniques of active and passive highway noise suppression are refined, methods used to measure noise are getting more sophisticated amid a political climate of less tolerance for highway noise in our cities and neighborhoods.

Keeping it Down

New solutions are coming in to play to control noise from America's Interstate highways, primary highways and arterial streets. Road agencies are spending more on noise mitigation. On new or capacity improvement projects, sound walls that were once considered an extravagance are now standard procedure.

Engineers are finding that the best solution to highway noise is a combination of sound wall, appropriate vegetation and a quieter pavement surface. Any combination of the three elements will help, because noise barriers can cost an average of $3.9 million per mile, according to current estimates by the Washington State DOT, with lower costs for rural barriers, and higher for urban.

Highway noise barriers can be of many configurations, including recycled plastic, wood, evergreens, gabion walls and precast concrete panels. Trees -- such as stands of thick evergreens -- have the potential to replace noise barriers, and are aesthetically pleasing, but are effective only in deep stands, requiring additional strips of right-of-way, as much as 100 feet wide.

Efforts to limit highway noise have focused on barriers. But because most of the noise originates at the tire-pavement interface, use of "quiet pavements" to quell noise there makes sense.

For portland cement concrete pavements, texture is added to improve friction and driver control, but done incorrectly it can add to pavement noise. Tine or groove depth, width, spacing and orientation are all major factors affecting tire-pavement noise. Transverse tinings with uniformly spaced tines a half inch or greater have been found to produce an objectionable tone, with pressure spikes at specific frequencies, that users interpret as a tire "whine." Randomly varying the transverse tine spacing, or skewing it, can reduce the tonal-quality problems.

Sophisticated asphalt pavement designs – such as polymer-modified, open-graded friction courses (OGFCs) – offer greater tire-pavement noise reduction than conventional asphalt mixes. Also, their porous nature also allows fast drainage of water and eliminates the problems of tire spray, glare and hydroplaning.

Even as the industry improves noise suppression practice, a new rule from the Federal Highway Administration takes effect this month (July 13). Articulated last year, the final rulemaking for 23 CFR 772, *Procedures for Abatement of Highway Traffic Noise and Construction Noise*, fine-tunes expectations for highway noise reduction and describes a three-part approach to highway noise:

- **Noise-Compatible Planning.** Local governments should regulate land uses to restrict noise-sensitive uses adjacent to highways.
- **Source Control.** EPA noise regulations set the maximum noise level 50 feet from the centerline of travel at 80 A-weighted decibels.
- **Highway Project Noise Mitigation.** FHWA sets a five-step process for transportation agencies managing highway project planning and design to identify and abate highway noise impacts.

Download a summary of the new rules at *environment.fhwa.dot.gov/strmlng/newsletters/sep10nl.pdf* The complete final rule may be accessed at|*edocket.access.gpo.gov/2010/2010-15848.htm*

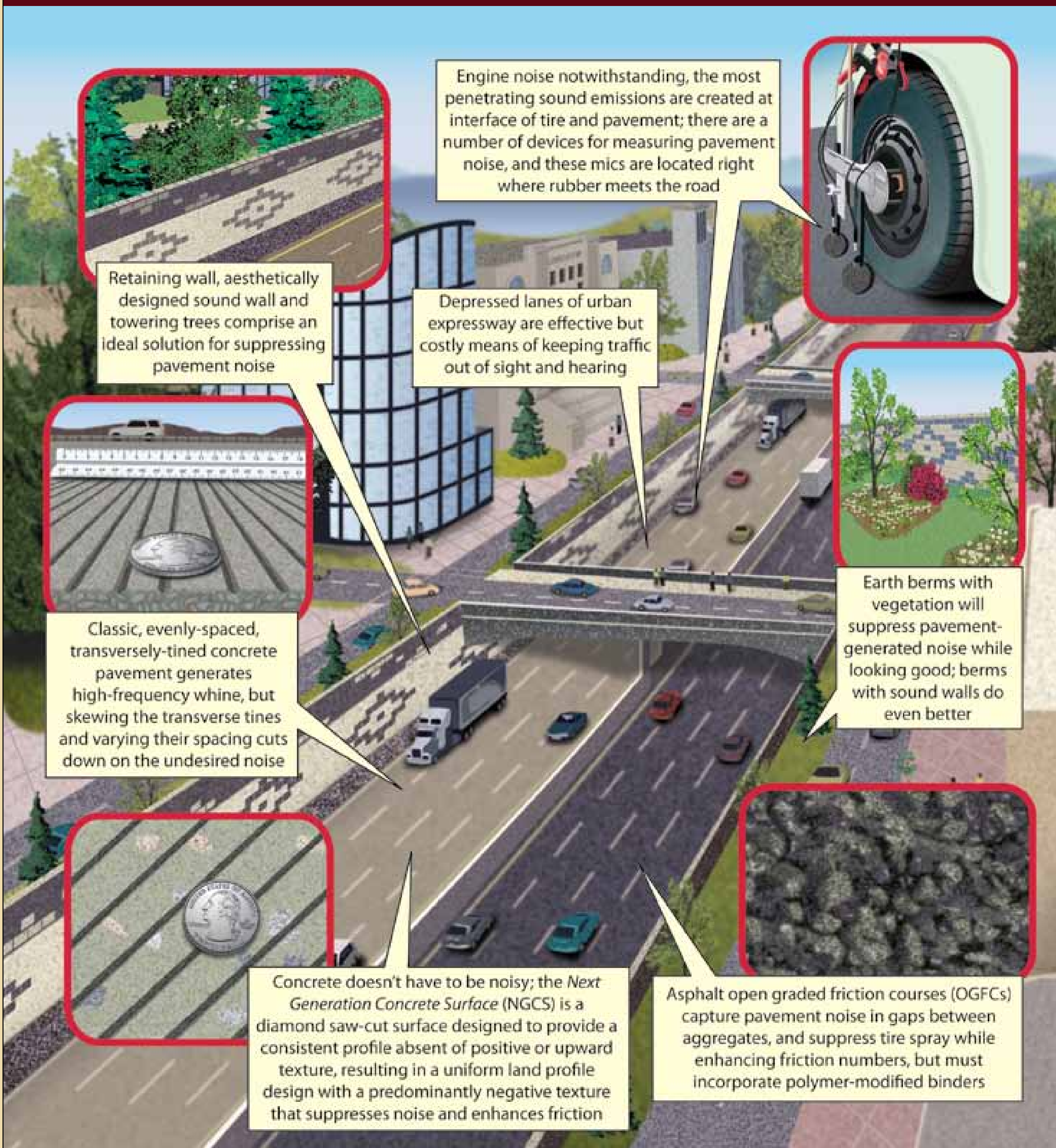
A recap of current federal and state initiatives in noise suppression – including a look at sound-absorbing noise walls

Illustration by Edd Hickingbottom

BETTER Roads

Hushing Pavement Noise

Options available in the fight against road roar



John Bray, Minnesota DOT

Producing a low-noise diamond ground surface – the NGSC – requires creating uniform and consistent negative-land profiles

– appears in the December 2010 *ROAD SCIENCE* (see *Gaining Influence in 2011*, December 2010, pp. 9-17).

Next-Generation Concrete Surface

This year, the concrete industry launched a portland cement concrete surface that will suppress noise from concrete pavements while enhancing friction and smoothness. A refinement of the pavement diamond-grinding process, the Next Generation Concrete Surface (NGCS) is being promoted by the International Grooving & Grinding Association and its allies, the American Concrete Pavement Association, Portland Cement Association and Purdue University.

When this innovative surface was used on an urban highway in Duluth, the response was overwhelming, IGGA reports. "Residents have called in asking how the roads became so quiet and it has even made the front page in the local newspapers," says IGGA Executive Director John Roberts.

The best way to understand the difference in the sound level with NGCS is to experience it; a high-traffic freeway with 240 vehicles will now sound comparable to only 120 vehicles of traffic, a substantial reduction in sound, IGGA reports. This is a considerable decrease for areas with a greater need for quieter roads, such as urban or residential areas.

The NGCS is a diamond saw-cut surface designed to provide a consistent profile absent of positive or upward texture, resulting in a uniform land profile design with a predominantly negative texture. NGCS is a hybrid texture that resembles a combination of diamond grinding and longitudinal grooving.

The texture is most easily constructed in a two-pass operation using diamond-tipped saw blades mounted on conventional diamond-grinding and grooving equipment. Testing has shown that these textures can be used for both new construction and rehabilitation of existing surfaces.

The construction method has two separate operations, reports the Washington State DOT in its April 2011 report, *Evaluation of Long-Term Pavement Performance and Noise Characteristics of the Next Generation Concrete Surface*. The first operation creates a flush ground surface and eliminates the joint or crack faults while providing lateral drainage by maintaining a constant cross-slope between grinding extremities in each lane.

The second operation provides the longitudinal grooves, Washington DOT reports. The longitudinal grooves are 0.125 inches wide, and 0.125 to 0.375 inches deep. The longitudinal grooves are spaced approximately 0.5 inches center-to-center. The grooves are constructed parallel to the centerline.

The NGCS is being promoted following three years of research at the Minnesota Road Research Project (MnROAD), the world's largest and most comprehensive outdoor pavement laboratory.

In early 2011, new NGCS test sections were constructed at the Virginia Tech Transportation Institute's *Smart Road* test facility near Blacksburg, Va. In January 2011, three test strips situated on two test areas were constructed, including a conventionally diamond-ground section, and an area that was conventional followed by longitudinal grooving of each half of the lane using two different groove spacings of 0.5 and 0.75 inches.

New Texturing Guide Specs

Also this spring, two new approaches were articulated for guide specifications for reducing tire-pavement noise on PCC pavements.

In the May 2011 publication, *Concrete Pavement Specifications for Reducing Tire-Pavement Noise*,

– developed by the Concrete Pavement Surface Characteristics Program (CPSCP) and published by the National Concrete Pavement Technology Center (CPTC) at Iowa State University – authors Robert Otto Rasmussen and Richard Sohaney of The Transtec Group, and Paul Wiegand of the Institute for Transportation at Iowa State, describe **method-based** (prescriptive) specs and **end-result** specs for suppressing PCC pavement-generated noise.

For the methods-based specs, four guide specifications (GS-1 through GS-4) have been developed. "[They] correspond to the four most commonly used concrete pavement textures: diamond grinding, drag (artificial turf), longitudinal tining and transverse tining," the authors write. "The practices described in the specifications have been demonstrated to increase the likelihood of constructing a durable, quieter concrete surface. Central to the specification is guidance for texturing the concrete surface, given that texture geometry has a paramount effect on tire-pavement noise. Guidance is also provided for curing to improve strength and durability of the surface, and thereby improve texture durability."

For the end-result specs, a recommended practice (PP-1) has been developed that includes guidance and sample specification language for owner agencies to evaluate tire-pavement noise of new concrete pavement surfaces. "The overall sound intensity level measured with the onboard sound intensity (OBSI) test method is designated as the quality characteristic," the authors write.

The authors single out transverse tining technique as a major culprit in PCC pavement noise. "Both longitudinal and transverse tining are routinely used by owner-agencies, particularly for high-speed facilities," Rasmussen, Sohaney and Wiegand wrote in May. "Achieving a quieter concrete surface is possible, but requires additional control, particularly for transverse tining, which is often associated with some of the loudest concrete pavements."

When using tined textures, grooves are imparted in the surface of a pavement while the concrete is plastic, they say. For best results, application of a drag pre-texture should be followed by subsequent tining.

"For longitudinal tining," the authors write, "the nominal spacing of the tines is 3/4 inch. For transverse tining, nominal spacing of 1/2 inch is specified. The nominal depth of the tined grooves in the plastic concrete is 1/8 inch."

The Tech Brief may be downloaded from the CPTC at cptechcenter.org/publications/surface_char_specs_tech_brief.pdf and the individual guide specs can be found at cptechcenter.org/projects/surface-characteristics/index.cfm

New Ways to Measure Noise

Integral to concrete's new attack on noise is a shift from measuring sound pressure remotely, to sound intensity directly at the source, the tire-pavement interface.

The key recommendations developed by the Concrete Pavement Surface Characteristics Center are largely based on tire-pavement noise tests conducted worldwide using microphones right at the tire moving on the pavement, write Rasmussen, Sohaney and Wiegand in a companion *Tech Brief* issued in May, *Measuring and Reporting Tire-Pavement Noise Using On-Board Sound Intensity (OBSI)*.

"OBSI measures tire-pavement noise at the source using microphones in a sound-intensity probe configuration mounted to the outside of a vehicle, near the tire-pavement interface," they say. "Measurements are performed while the test vehicle drives across the pavement of interest."

Sound and noise can be a relative experience. A rock concert produces sound levels at about 110 decibels. A quiet night actually produces some 30 decibels of sound. But only levels above 85 to 90 decibels are thought to pose health risks.

Sound levels are measured exponentially. One expert describes it this way: Assuming two planes with the same individual sound level (3 decibels) are added for every double. If a plane taking off creates 100 decibels of noise, two planes would make 103 decibels, four planes 106 decibels, and eight 109. Highways, roads and streets routinely produce decibel readings of from 65 to 85 decibels.

When a sound level (such as 90 dBA) is reported, it is most often a measure of the amplitude of sound pressure changes, the authors add. "Sound intensity is different from sound pressure in that it has both amplitude and an associated direction," they write, making it a more meaningful criterion for analyzing noise emissions.

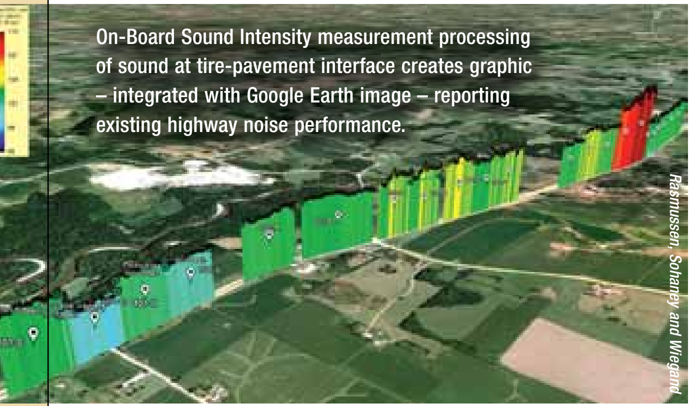
Benefits of OBSI include:

- The directional characteristic of the probe makes it better-suited for measuring a specific noise source, while attenuating sounds from other sources in other directions (such as engine or exhaust noise);
- Sound intensity is much less contaminated by "random" noise, such as wind noise generated as the vehicle is moving; and
- Because sound intensity measures the acoustic energy propagating away from the source to the roadside, it correlates well with sound measured at the roadside (known as pass-by or wayside measurements).

The new *Tech Brief* may be downloaded at*cptechcenter.org/publications/surface_char_specs_tech_brief.pdf*

New-generation sound wall on Windsor-Essex Parkway in Ontario boasts aesthetic pattern and clear, transparent panels which obviate 'Berlin Wall' look

Ontario Ministry of Transportation



On-Board Sound Intensity measurement processing of sound at tire-pavement interface creates graphic – integrated with Google Earth image – reporting existing highway noise performance.

Rasmussen, Sohaney and Wiegand

OGFCs Quell Noise at Surface

Open-graded friction courses offer state DOTs a better-performing, driver-friendly pavement. These new-design OGFC pavements feature an "open" aggregate structure (without fines) in which larger-sized aggregate is held in place by polymer-modified and fiber-modified Superpave performance-graded liquid asphalts.

This open structure of 15 percent or more voids allows water to drain right through the driving or friction course to an impervious intermediate course below, and out the side and into edge drains or roadside ditches. The result is the near-complete elimination of tire spray and hydroplaning, making a safer pavement.

Also, because noise generated at the tire/pavement interface is attenuated within the spaces between the aggregate, they are significantly quieter pavements. The noise reduction can be on the order of 3 to 5 decibels.

An OGFC describes a layer of asphalt that incorporates a skeleton of uniform aggregate size with a minimum of fines. Typically, OGFCs in the past have a void content as low as 12 percent and as high as 15 or 16 percent. But the new generation of OGFCs that are being built in Europe have considerably higher air void contents, up in the range of 17 to 22 percent. They are more open, with more voids.

Most OGFCs are 3/4-inch thick, and never thicker than 2 inches. The OGFC should be elevated above the shoulder, as the water drains onto the shoulder and hence to a roadside ditch. Open-graded, proprietary thin surfacings such as *Novachip* and its clones qualify as OGFCs.

In dense-graded asphalt mixtures, reports The Asphalt Institute, a thin film of asphalt plus compaction effort – are required to keep the mix glued together. In short, the final density of dense-graded mixes is a direct measure of the strength and durability of the mix. But the OGFC mix, according to the AI, uses a grading of mostly 3/8-inch stone, the idea being to build up a thick film of asphalt on the stone without the mixture draining or flushing. The asphalt film thickness is usually four to six times that of a dense-graded mix.

"If properly designed, the asphalt in an OGFC does two jobs," AI says. "First, it acts as a binder or glue. Second, since the mix is open to water and air, it acts as a waterproofing agent and protective coating to resist oxidation and rapid aging of the asphalt cement itself."

Today's OGFCs are polymer-modified and include spun mineral or cellulose fibers to preclude drain-down of asphalt binder during transport and placement. Use of polymer modifier or fiber does not preclude the other; instead, each complement the other in the liquid asphalt. The fibers disperse evenly, and despite their tiny size, overlap and form a mat, which keeps the liquid asphalt from draining from the top to the bottom of the layer before it cools, not unlike the action of gauze in keeping a wound from seeping.

But an application in May 2011 in South Carolina showed that fibers can be eliminated from an open-graded porous asphalt pavement. Use of Evotherm warm-mix asphalt additive permitted an open-graded mix that did not require addition of mineral or cellulose fibers to prevent draindown, a substantial savings. It also permitted elimination of lime as an adhesion promoter resulting in substantial savings.

Sound Walls Go Mainstream

From a start as an extravagance decades ago, sound walls now have gone mainstream, as they are seen more and more on new urban and suburban expressway projects, and as retrofits on existing highways.

The FHWA requires DOTs to complete a sound study any time it plans to add through lanes to an existing highway or change the location of a road. "Sound walls can help lessen the noise impacts of the roadway improvement and provides noticeable sound reduction for houses closest to the highway," says the Missouri DOT.

A sound wall can reduce noise levels from 5 to 10 decibels. In Missouri, communities are eligible for a sound wall only if noise levels are at 66 decibels or above. According to the Washington State DOT, 66 decibels was chosen as the impact threshold because researchers have shown that above this level, conversation between two people standing 3 feet apart and speaking in a normal voice is impaired.

Missouri criteria for construction of a sound wall includes:

- the sound wall must reduce noise levels by at least 5 decibels for all benefited homeowners,
- the sound wall must benefit more than one homeowner,
- the sound wall must be 18 feet or less in height,
- the sound wall must not pose a traffic safety hazard, and
- the majority of the benefited residents must agree that a sound wall is desired.

Sometimes state and local agencies will cooperate in construction of sound walls for existing freeways. For example, Missouri will conduct a sound study to review the need for sound mitigation near existing highways when cities and counties participate in the cost of the design and the construction of the wall. The local government agency must provide 50 percent of the design and construction cost. MoDOT will provide the 50 percent matching funds. If the construction cost of the sound wall project exceeds $30,000 per benefited resident, the local government agency must pay 100 percent of the cost above $30,000.

Sound walls can be a costly undertaking. In Washington State, the DOT estimates current construction costs are averaging $53 per square foot. "This translates into a 14-foot-high wall costing about $3.9 million per mile," the DOT says. "Construction costs for rural barriers may be lower and urban barriers may be much higher. The higher urban costs are associated with the existence of other infrastructure – like retaining walls or water pipes – that may need to be retrofitted or moved to allow the placement of barrier."

A Choice of Materials

Precast concrete panels – due to their quick erection capability in the field – constitute the bulk of sound walls today. Precast panels also permit aesthetic textures to be integrated into a project. They can be as bland as an imitation of hewn concrete block, or as attractive as a motif incorporating Native American designs, as seen often in the American Southwest.

Concrete panels and block are

muscling out competing materials like wood, steel and plastic on a national basis, but in doing so quite often are going up against each other in bids. In 2000, concrete and block represented almost two-thirds of total material usage, according to a spokesman for the FHWA Office of Environment and Planning.

Because of the growth in sound wall applications, and the fact that highway noise barriers can be so expensive, barrier design must as efficient and cost-effective as possible. That's why FHWA released, in March 1998, a state-of-the-art model for predicting noise impacts in the vicinity of highways, the FHWA *Traffic Noise Model*.

The current Version 2.5 was released in April 2004. The FHWA TNM is a computer program that incorporates advances in personal computer hardware and software to improve upon the accuracy and ease of modeling highway noise, including the design of effective, cost-efficient highway noise barriers. For more information, visit fhwa.dot.gov/environment/noise/traffic_noise_model

Although precast concrete and masonry are the leading materials for sound walls, wood often is thought of first for sound walls. Other competing materials include steel, plastic and recycled products. The concrete products industry is fighting against lower-priced materials by promoting lifecycle costing versus competing materials.

Wood has declined in usage because of durability problems compared to concrete, difficulties in cleaning of graffiti, and the disfavor of use of imported wood from tropical rain forests, which had been the prime source. Wood also suffers because preservatives such as creosote emit volatile organic compounds to the atmosphere.

Use of alternate materials may have been boosted with the January 1999 Transportation Research Board-sponsored publication of *Noise Barriers Using Recycled-Plastic Lumber* (Hag-Elsafi, Elwell, Glath and Hiris).

This paper, out of the New York State DOT, described use of "lumber" fashioned from recycled plastic extruded into classic lumber sizes, and placed in wood or steel frames. They mentioned then-competitive costs per square meter of $161-194 for plastic lumber with wood frames, and $226-269 with steel frames. ❖

There's MORE RoadScience in our digital issue at WWW.BETTERROADS.COM. See how Virginia is evaluating quiet pavements AND take a look at clear-top noise barriers.

Clear-Top Noise Barriers

Sound walls continue to undergo refinement, such as usage of sound-absorbing surfaces. They also can be made more attractive by use of added transparent panels, as was seen recently in Ontario, Canada.

When Ontario's Ministry of Transportation was looking to include noise barriers in the design of the Windsor-Essex Parkway, it aimed to reduce unwanted sound while retaining an aesthetically pleasing environment. It settled on Paraglas Soundstop noise barrier sheet, from Evonik Cyro. The sheeting allows the integration of a transparent panel above solid panels, enhancing the visual impact of the noise barrier from both the residential and driver perspectives.

Aiding in the decision-making process were local residents and business owners, elected officials and stakeholders. All were consulted by the Ontario Ministry of Transportation during a series of more than 300 events.

"During the design and proposal stage of this project, we met with the public on barrier design possibilities, and an overwhelming majority was in favor of transparent panels," says Dennis Regan, senior project manager, Ontario Ministry of Transportation. "Clear panels provide a wide range of benefits, including improving the view from the highway, lowering the visual intrusiveness of the barrier, reducing noise levels and breaking up the visual monotony."

Unlike traditional noise barriers that are manufactured from precast concrete panels that decrease visibility, transparent sound walls are ideal for blocking highway noise while preserving visibility and light. New technology makes them resistant to weathering, retaining clarity and strength throughout years of harsh outdoor use. The panels can be easily integrated into precast wall systems and virtually any other sound wall system.

Installation of the barriers was completed in the winter of 2010, and they will help to provide residents with mitigation from construction noise while the state-of-the-art road is completed. Soundstop has noise reduction characteristics that are comparable to concrete panels, according to the manufacturer.

In the United States, the product has been featured on projects including the Miami-Dade Expressway in Florida, Marquette Interchange in Milwaukee, the Woodrow Wilson Bridge connecting Maryland and Virginia, and for multiple walls in East and New Brunswick, N.J. Installations total more the 4 million square feet worldwide in 2010, the maker says.

Virginia Evaluates Quiet Pavements

In late May of this year, the office of Virginia Gov. Bob McDonnell announced that he had signed legislation directing the Virginia DOT to construct several demonstration projects – both portland cement concrete and hot-mix asphalt – to further study "quiet pavement" technologies. These projects will help determine how well the new pavements perform over two winters in Virginia.

"VDOT's research arm, the Virginia Center for Transportation Innovation and Research, has been a national leader in developing real-world testing scenarios for the latest highway technologies and working with VDOT engineers to implement them for the benefit of all who use Virginia roads," McDonnell says. "These demonstration projects will take results from one recent study and put them to work to make our roads safer and last longer, and to improve the quality of life for those living near the roadways."

HB 2001 amends a 2009 Virginia law requiring VDOT to consider using pavement materials that reduce tire noise when resurfacing appropriate roads. The Quiet Pavement Task Force is a cooperative group consisting of representatives from VDOT and the asphalt and concrete paving industries. The group studies and identifies roads around the Commonwealth that would be candidates for quiet-pavement installations.

VDOT will install five demonstration projects to assess the performance of such materials for two years. They are all on four-lane, divided high-speed roads with good underlying pavement structures.

The three locations selected for the **asphalt "quiet" technologies** will be on the Route 7 Bypass in Leesburg, Route 199 west of Williamsburg and Route 288 near Chester. Concrete demonstration projects will be installed on a section of Interstate in Hampton Roads and Route 76 (Powhite Parkway) in Richmond.

Following a year-long pilot begun in 2008, VDOT obtained positive results from a quiet pavement installation on a section of Route 234 in Manassas using a "porous friction course," more commonly called an "open-graded friction course" (OGFC). This mix allows air and water to seep down from the road surface away from tires, reducing hydroplaning, tire noise and splash-and-spray. The improved drainage also cuts wet-night glare and improves the visibility of road markings. Noise created at the tire-pavement interface is attenuated within the gaps between aggregate at the pavement surface.

The Virginia Center monitored the Route 234 project and found that, based on initial cost and the year-long performance of the material, the asphalt porous friction course is cost-competitive with traditional hot-mix asphalts. The VCTIR report on the project can be found at*vtrc.virginiadot.org/PubDetails.aspx?PubNo=09-R20*

The"**quiet" concrete projects** will employ two finishes applied to existing concrete pavements. The first will be a simple diamond-grinding process used to restore ride quality by knocking off high spots in the pavement; the second is a multi-step process, which follows the diamond-grinding process with a smoother grind and a longitudinal groove, that is, an NGCS. "The second finish was designed specifically to reduce tire-pavement noise," the Virginia Center says. "This will be the first time the second process will be used in Virginia." ❖