SPRING 2013
Volume 25, Number 1

Asphalt Technology News

In This Issue

- NCAT Pavement Preservation Effectiveness Study Will Help Agencies Make Cost-Effective Maintenance Decisions —*page 1*
- Hydrated Lime—Still the best Anti-Strip in Georgia —*page 3*
- Coarse Aggregate Polishing Resistance is Not Enough to Ensure Adequate Surface Friction —*page 5*
- NCHRP 9-47A Offers Recommendations for WMA Mix Design Changes —*page 6*
- Asphalt Forum —*page 7*
- Asphalt Forum Responses —*page 8*
- Specification Corner —*page 10*
- Research Roundup —*page 12*

  Improving the Durability of Open-Graded Asphalt Mixtures
- Training Opportunities —*page 15*

  New Course Focuses on Sustainable Pavements

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

NCAT Pavement Preservation Effectiveness Study Will Help Agencies Make Cost-Effective Maintenance Decisions

The new Preservation Group (PG) experiment will provide answers for cash-strapped state and local agencies that need cost-effective ways to maintain existing asphalt roadways. Budgets are tight, but agencies still have the same task: keeping aging pavements in good condition for the driving public. When applied at the right time, pavement preservation treatments, such as chip seals, micro surfacing and thin asphalt overlays, can restore a smooth, safe driving surface while saving money on future rehabilitation costs. Among the challenges faced by engineers are determining what type of treatment to perform and when to apply it so that life cycle cost is minimized. The results of the PG study will give pavement engineers better tools to meet those challenges.

"What's unique about our approach is that we are not comparing individual pavement preservation techniques. Instead, we are quantifying the life-extending benefits of each treatment as a function of pretreatment pavement conditions," says NCAT Assistant Director and Test Track Manager Dr. Buzz Powell.

Sponsors of the PG study include seven state DOTs—Alabama, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina and Tennessee—in addition to FP^2, previously called the Foundation for Pavement Preservation. Test sections are located on Lee County Road 159 and the 1.7-mile NCAT Pavement Test Track.

As part of the PG study, traffic is continuing on several sections from the fourth Test Track research cycle. These sections include warm-mix asphalt (WMA) and 50 percent RAP mixes, all with a total asphalt thickness of seven inches. Preservation treatments will be applied when a predetermined level of distress is reached, and performance will be further monitored as heavy truck traffic continues at the track.

Lee County Road 159

The larger part of the study is a half-mile segment of nearby Lee County Road 159 (LR 159). This road provides access to a quarry and asphalt plant, with pretreatment pavement conditions varying from good to poor. Pavement distresses were greater in the outbound lane due to loaded trucks leaving the quarry and asphalt plant. Poorer pavement conditions

—Continued on Pg. 2

Completed LR 159 Project

—Continued from Pg. 1

also existed in the right wheelpath of each lane where the road was previously widened. Figure 1 shows a schematic of pretreatment pavement distresses, with 2500 ft. marking the stop sign at the end of the project farthest from the quarry and asphalt plant.

From July to September 2012, a variety of preservation treatments, listed in Table 1, were applied to LR 159 in 25 sections, each 100 feet in length and spanning both lanes. Each section/cell is further divided into 40 subsections to facilitate the development of individualized life cycle performance curves for each treatment relative to pretreatment condition.

1. Fog Seal	14. Micro Surfacing over FiberMat®
2. FiberMat®	15. Micro Surfacing over Scrub Seal
3. Control	16. Scrub Seal
4. Control	17. FiberMat®
5. Control with Crack Seal	18. 4.75 mm (PG 67) over FiberMat®
6. Single Chip Seal	19. 4.75 mm (PG 67)
7. Single Chip with Crack Seal	20. 4.75 mm (PG 67) over Foamed Recycle
8. Triple Chip Seal	21. 4.75 mm (PG 76)
9. Double Chip Seal	22. Ultra-Thin Bonded Layer
10. Micro Surfacing over Single Chip Seal	23. 4.75 mm (50 percent RAP)
11. Micro Surfacing	24. 4.75 mm (5 percent RAS)
12. Micro Surfacing with Crack Seal	25. 4.75 mm (Highly Polymer-Modified Asphalt—HiPM)
13. Double Micro Surfacing	

Table 1. Pavement Preservation Treatments Applied to Each 100-ft. Section of LR 159

While some of the preservation treatments, such as chip seals, have been used for decades, others are relatively new approaches to pavement preservation. For instance,

- *FiberMat®* is designed to act as a crack-absorbing membrane and incorporates two applications of polymer-modified asphalt emulsion, with a layer of fiberglass strands between them. A layer of crushed aggregate is then spread and rolled into the fiberglass-reinforced emulsion.
- *Micro surfacing* is slurry of polymer-modified emulsion, fine aggregate, cement, and water. Specialized equipment is used to mix the components and spread the slurry over the existing pavement surface in a continuous operation.
- *Foamed recycle* refers to a 100 percent RAP cold mix that is produced using central plant recycling. In section 20 of LR 159, six inches were removed and replaced with this recycled material, which contains 2 percent foamed PG 67-22 binder.
- *Ultra-thin bonded layer* uses a specialized paver to apply a thick polymer-modified emulsion to the roadway surface immediately in front of the auger-box where the gap-graded hot mix asphalt is spread beneath the paver's screed.

—Continued on Pg. 3

Figure 2. Placement of FiberMat ®

Figure 3. Application of scrub seal treatment

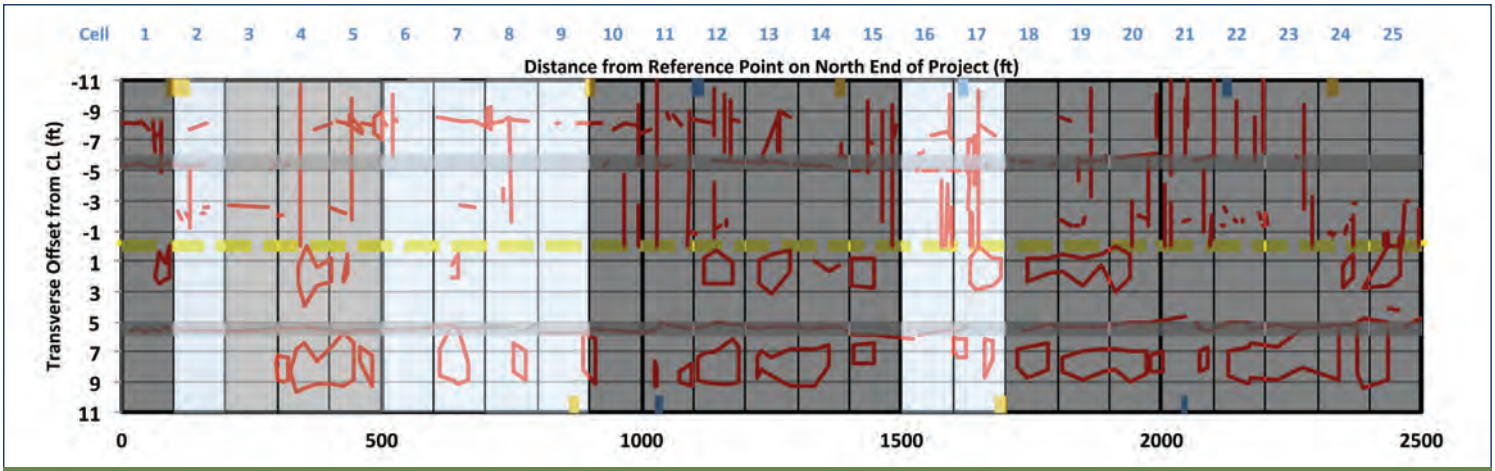

Figure 1. Schematic of Pretreatment Pavement Distresses on LR 159. The red lines represent cracks, while red polygons indicate an area of interconnected cracking. Blocks of cells are shaded to indicate an area of similar preservation treatments applied (refer to Table 1 for specific treatments in each cell). The original roadway (prior to previous widening) is also delineated.

—Continued from Pg. 2

Several sections of LR 159 contain variations of a 4.75 mm nominal maximum aggregate size (NMAS) mix with a proven performance record through three traffic cycles at the NCAT Pavement Test Track. The control mix in section 21 uses a polymer-modified PG 76-22 binder, while other experimental sections incorporate PG 67-22 binder. One includes 50 percent fine fractionated RAP and another contains 5 percent reclaimed asphalt shingles (RAS). Section 25 has a 4.75 mm NMAS mix containing highly polymer-modified (HiPM) binder with a PG 88-22 grading. This section is closest to the stop sign at the end of the project and had severe pretreatment distresses. All 4.75 mm NMAS mixes were placed at a thickness of 0.75 inch.

The quarry and asphalt plant located on LR 159 are operated by Martin Marietta and East Alabama Paving, respectively. Data-sharing agreements between them and NCAT will provide load history throughout the life of the project, and pavement condition will be assessed regularly. Weekly monitoring includes measurements of rut depth, mean texture depth (MTD) and international roughness index (IRI) via the ARAN van. According to Dr. Mary Robbins, assistant research professor at NCAT, a video record of each lane is also taken weekly from the back of the van at a speed of 10 mph. The video is then processed using software to identify the location and extent of cracking. Monthly monitoring includes subgrade moisture, in addition to falling-weight deflectometer (FWD) testing and friction testing using a full-size skid trailer with a ribbed tire under wet conditions.

Figure 4. Micro surfacing

Figure 5. Paving Thin Asphalt Overlay with 4.75 mm NMAS mix

This research project eliminates the bias that would result from comparing preservation treatments on various roads with different structural and traffic conditions. Data from the PG study will define a performance curve for each treatment, quantifying the relationship between existing pavement distresses and how much time and traffic each treatment can withstand before the pavement returns to its pretreatment distressed state. Using these performance curves, state and local agencies will be able to objectively decide which treatments will provide the most cost-effective maintenance solutions for their individual projects. Comparisons with the untreated control section will also allow agencies to determine the life-extending benefits of preservation treatments and enable decision-makers to prioritize pavement maintenance investments.

Hydrated Lime—Still the Best Anti-Strip in Georgia

Stripping, or moisture-induced damage, occurs when the bond between asphalt binder and aggregate particles deteriorates due to the presence of moisture in an asphalt pavement. As the bond weakens, premature failure of the pavement can occur. This problem has been documented and studied for more than three quarters of a century, with the earliest research on stripping dating back to 1932.

Georgia DOT (GDOT) began requiring the use of a liquid anti-strip agent in 1969. However, a large-scale investigation of interstate pavements in the early 1980's revealed that stripping was still a common problem, leading GDOT to implement the use of hydrated lime to improve resistance to moisture damage. Thirty years later, innovations in materials and technology prompted GDOT, in partnership with NCAT, to revisit the issue and evaluate the effectiveness of various anti-strip agents.

In the first part of the study, three anti-strip agents were evaluated in a 12.5 mm Superpave surface mix. Hydrated lime (at a rate of 1.0 percent of the dry aggregate weight) was compared with a representative liquid anti-strip agent chosen from Georgia's Qualified Product List and a new warm-mix additive that also exhibits anti-strip properties. Laboratory specimens were prepared using two granite aggregate sources, and field test sections were placed on a state route in southern Georgia, with cores being taken at the time of construction and after two years.

All tensile strength testing was performed using the GDT 66 test method, which differs somewhat from AASHTO T 283. For instance, samples undergo vacuum saturation for a period of 30 minutes regardless of level of saturation. After removing conditioned samples from a 140°F (60°C) water bath, all samples, including those that did not undergo vacuum saturation, are placed in a 55°F (12.8°C ± 2°C) water bath for 2 hours. Also, the loading rate for tensile strength testing is 0.065 in/min. GDOT requires a minimum tensile strength ratio (TSR) of 0.80, and all individual samples must have a tensile strength greater than 60 psi. A mix is also considered passing if the

—Continued on Pg. 4

Figure 1. A Recent Localized Pavement Failure Caused by Stripping of an Intermediate Asphalt Pavement Layer

—Continued from Pg. 3

TSR is greater than 0.70 as long as all individual samples have a tensile strength greater than 100 psi.

Hydrated Lime Shows Excellent Performance in the Lab

Tensile strength testing was conducted on lab-prepared mix after 0, 1, 5, and 10 freeze-thaw cycles. Mixes containing the liquid anti-strip (designated LAS) had TSRs less than 0.80 after 5 cycles for both A and B aggregate sources and after 10 cycles for aggregate B. Mixes with the warm-mix additive (referred to as WMX) failed to meet TSR criteria after both 5 and 10 freeze-thaw cycles for both aggregate sources and after 1 cycle with aggregate B. However, the mixes treated with hydrated lime performed well, meeting the 80 percent TSR criteria for all freeze-thaw cycles tested. Additionally, the samples containing hydrated lime exhibited the highest tensile strengths and highest TSRs, compared with both LAS and WMX.

Statistical analysis indicated that the most significant variable was the anti-strip agent used. It was also apparent from statistical analysis that 5 and 10 freeze-thaw cycles produced the most discriminating predictions of moisture susceptibility.

Unconfined dynamic modulus testing was conducted at the temperatures and frequencies recommended in AASHTO PP 61-10. Since this project used a PG 67-22 binder, the high test temperature was 40°C. The moduli were slightly higher for the mixes containing hydrated lime, but results were generally statistically equivalent for all three anti-strip agents used. Results for flow number testing (according to AASHTO TP 79-11) were best for mixes containing WMX, while mixes treated with LAS had the lowest flow number results.

Field Test Results Confirm Performance

The 12.5 mm Superpave mix produced for the field test sections contained 24 percent RAP. The LAS was pre-blended at the terminal at a rate of 0.5 percent by weight of asphalt, while WMX was added to a tanker at the rate of 2.0 percent by weight of asphalt. Following delivery to the plant, the WMX-treated binder was circulated in a storage tank overnight.

Samples of plant mix were obtained and lab-compacted for moisture sensitivity testing per GDT 66. All specimens yielded tensile strengths greater than 100 psi and had TSRs of at least 0.80. Cores taken after construction were similarly tested; however, only the cores containing hydrated lime and LAS met the TSR requirement, and only the cores containing hydrated lime had average tensile strengths greater than 100 psi.

Additional cores were evaluated for rutting and stripping potential using the Hamburg Wheel Tracker, per AASHTO T 324-04, except that half of the cores underwent one freeze-thaw cycle prior to testing. GDOT uses Texas DOT's criteria for interpreting Hamburg results—for PG 64 binders, rutting should be less than 0.5 inch after 10,000 passes. Furthermore, a moisture-resistant mix should have a stripping inflection point greater than 10,000 passes. All samples met the Hamburg rutting criteria; however, the WMX samples failed with regard to stripping inflection point. The Hamburg results yielded rankings similar to the TSR results, with hydrated lime performing best, followed by LAS and WMX.

Cores were also taken two years following construction to evaluate performance over time. For TSR testing, cores were evaluated both with and without a freeze-thaw cycle. While the hydrated lime cores after two years had excellent results, tensile strength decreased after a freeze-thaw cycle. The LAS cores produced consistent and acceptable results both with and without a freeze-thaw cycle. Tensile strength for the WMX cores was greater than that initially after construction, indicating that over time, aging of the binder occurs so that strength is comparable to that of other anti-strip treatments (Figure 2).

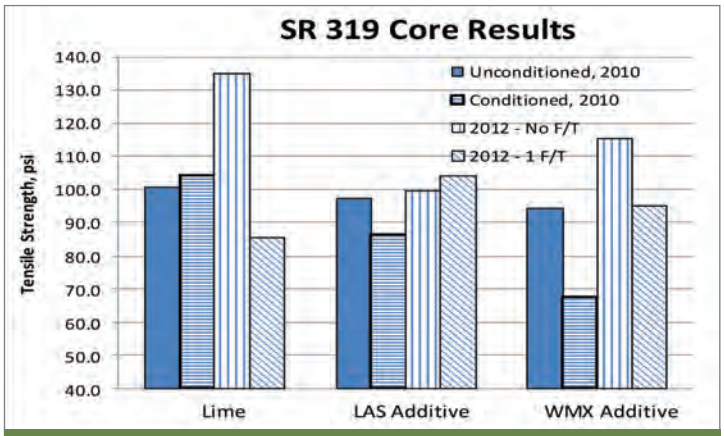

Figure 2. Tensile Strength of Project Cores

Hamburg Wheel Track testing was also conducted on cores taken after two years. These samples were subjected to one and three freeze-thaw cycles. Hydrated lime and WMX samples exceeded 20,000 passes for both rutting and stripping inflection point, but LAS cores did not perform as well, with premature rutting failure occurring for samples that underwent one freeze-thaw cycle. Hamburg results after two years also indicated that the WMX-treated mix gained strength over time as the asphalt binder ages.

Georgia's current specifications require hydrated lime to be used as an anti-strip agent for asphalt mixes on all state and federal routes. Based on these test results from both lab-prepared mix and field test sections, it can be concluded that hydrated lime is still the best anti-strip in Georgia.

Coarse Aggregate Polishing Resistance is Not Enough to Ensure Adequate Surface Friction

Dr. Mike Heitzman, Assistant Director, NCAT

Decades ago, asphalt surface mixes used on high-speed, high-traffic routes commonly used ¾-inch top sized aggregates. The amount of coarse aggregate in these mixtures was typically 55 to 70 percent of the total aggregate. As a result, early friction standards were based on testing the polishing characteristics of the coarse aggregate. The British Pendulum test (AASHTO T 279 and T 278) is one example of a laboratory test that only examines the polishing characteristics of the coarse aggregate. Another approach relies on aggregate mineralogy to classify friction aggregate.

For some agencies, an abundance of aggregates resistant to polishing makes it easy to specify pavement surface mixtures with good friction properties. Other agencies, however, are in geologic regions that do not have good friction aggregate and must specify friction materials that have to be imported, which greatly increases pavement construction and maintenance costs. For areas deficient in friction-quality aggregate, the surface mixture specifications typically require a certain percentage of high-quality, high-cost coarse aggregate to achieve the desired level of friction properties.

Over time, the types of asphalt surface mixtures have changed. The understanding of mixture properties to support heavy traffic has improved, and surface course mixtures have shifted to smaller maximum aggregate sizes and finer gradations so that they can be constructed thinner and smoother. A consequence of this mixture evolution is mixtures with only 30 to 45 percent coarse aggregate. Many surface courses now use 9.5 and 4.75 mm nominal maximum aggregate size (NMAS) mixes. Highway agencies need to recognize the influence of the coarse aggregate reduction on the amount of friction aggregate and differences in texture of the surface layers. Friction should rely on more than a specification on coarse aggregate characteristics. Some agencies use field test sections to evaluate the friction characteristics of surface layers with new aggregate sources or blends of aggregates. Field studies are costly to construct, take years to monitor, and put public safety at risk if a test section fails to maintain acceptable friction.

Figure 1. NCAT Three-Wheel Polishing Device (TWPD)

Figure 2. Dynamic Friction Tester (DFT)

To address the need to more efficiently characterize friction characteristics of modern surface layers, NCAT developed a laboratory testing process that evaluates the changes in friction and texture of an asphalt mixture. Polishing and testing the mixture, not just the coarse aggregate, brings this laboratory testing process closer to relating the results to field friction performance. Testing after incremental periods of polishing creates a friction performance curve specific to the combination of aggregates used in the mixture. The NCAT test protocol uses the NCAT Three Wheel Polishing Device (TWPD) and ASTM 1911 Dynamic Friction Tester (DFT). Texture changes in the surface can also be assessed using the Circular Track Meter according to ASTM E 2157. This test protocol has proven ability to properly rank the friction of surface mixtures in the laboratory to the friction performance ranking of the same mixtures placed on test sections of the NCAT Pavement Test Track. A number of agencies and aggregate suppliers have contracted with NCAT to perform comparative tests on alternative asphalt surface friction mixtures.

NCAT friction research is currently studying two key topics: (1) improving the correlation between laboratory and field data and (2) better defining the amounts of friction aggregate necessary to maintain a safe pavement surface. One issue that makes the correlation effort challenging is the inherent variability in field skid trailer testing due to differences in tire-wheel path location on replicate tests, fine debris or oily fluid residue on the pavement surface, and temperatures during the time of testing. As asphalt surface mixtures evolve, we need to efficiently determine the most cost-effective ways to ensure safe pavement surfaces. Simply measuring the polishing resistance of the coarse aggregate is not enough.

NCHRP 9-47A Offers Recommendations for WMA Mix Design Changes

A recent NCAT survey revealed that warm-mix asphalt (WMA) accounted for 20-30 percent of the total plant mix produced in the U.S. in 2011. This represents a significant rise in WMA usage, up from 13.2 percent in 2010, as reported from a previous NAPA survey. Agencies and contractors alike are reaping the benefits of using WMA, including lower energy costs, reduced emissions and enhanced workability. Across the nation, 26 states have implemented WMA usage or are in the process of implementation.

One concern has been how to ensure that warm-mix is properly designed. To date, almost all WMA produced has used a "drop-in" approach, meaning that a conventional hot-mix design is simply produced at a lower temperature by means of a WMA technology (process or additive). NCHRP 9-43 concluded that a separate WMA mix design procedure was unnecessary, but modifications to the Superpave mix design procedure (AASHTO R35) were recommended in the form of an appendix entitled "Special Mixture Design Considerations and Methods for WMA," published in NCHRP Report 691.

		In-Place Density, % G_{mm}				Avg. Rut Depth, mm		Avg. Rut Depth, mm	
		One-Year Cores		Two-Year Cores		One Year		Two Years	
Project	Technology	WMA	HMA	WMA	HMA	WMA	HMA	WMA	HMA
Walla Walla, WA	Maxam Aquablack	95.2	95.9	95.7	96.3	0	1	0	5
Centreville, VA	Astec DBG	93.5	94.4	93.4	93.8	0	0	3	3
Rapid River, MI	Evotherm 3G	96.9	97.6	96.0	96.6	0	0	0	0
Rapid River, MI	Advera	96.5	97.6	97.0	96.6	0	0	0	0
Baker, MT	Evotherm DAT	94.0	93.6	93.3	93.7	<0.5	<0.5	<1	<1
Munster, IN	Wax	92.9	92.9	93.2	93.5	0	0	0	0
Munster, IN	Gencor Foam	94.0	92.9	93.5	93.5	0	0	0	0
Munster, IN	Evotherm 3G	93.0	92.9	93.3	93.5	0	0	0	0
New York, NY	BituTech PER	94.4	93.9	-	-	<1	1	-	-
New York, NY	Cecabase	93.4	93.9	-	-	<0.5	1	-	-
New York, NY	SonneWarmix	92.3	93.9	-	-	0	1	-	-
Jefferson Co, FL	Terex CMI Foam	91.8	92.6	91.8	91.5	2	2	3	3
Casa Grande, AZ	Sasobit	94.5	93.8	-	-	3	3	-	-

Table 1. Pavement Densification and One- and Two- Year Rut Depths for WMA and HMA Sections

The appendix recommends minor changes to AASHTO R35 when designing WMA, including:

- additional laboratory equipment,
- blending chart analysis for incorporating RAP in WMA,
- specimen fabrication procedures for individual WMA processes
- evaluations for coating, compactability, moisture sensitivity and rutting resistance.

Further research under NCHRP 9-47A, completed by NCAT and Advanced Materials Services, has recommended modifications to the appendix. NCHRP 9-47A was tasked with documenting field performance of a wide range of WMA technologies across the U.S., comparing engineering properties of WMA to HMA, evaluating energy savings and emissions reductions for WMA production, as well as evaluating the WMA mix design appendix developed in NCHRP 9-43. A summary of the recommended changes follows.

Additional Laboratory Equipment

Section 3.1.1 of the appendix describes the mechanical mixer used to prepare mixes in the lab, either a planetary or a bucket mixer. Note 1 states that mixing times for bucket mixers should be established based on coating evaluations. However, NCRHP 9-47A conducted a total of 10 WMA mix design verifications using a bucket mixer and found in every case that sufficient coating was achieved using the 90-second mixing time recommended in the appendix for planetary mixers. Thus, it is recommended that Note 1 be removed.

Section 3.3.1 discusses the laboratory asphalt foaming devices used to simulate plant WMA foaming processes. NCHRP 9-47A recommends that this section include the option of using mix produced during a trial run at an asphalt plant in lieu of lab-produced mix. This recommendation is based on challenges associated with using laboratory foaming systems.

Volumetric Design

Specimen fabrication procedures for individual WMA processes are given in section 7 of the appendix. However, the appendix does not specifically state that lab-produced WMA should be used in the volumetric design process. Based on NCHRP 9-47A findings, selection of a mix's optimum asphalt content based on traditional volumetric criteria should be accomplished per AASHTO R35 without using the WMA additive or technology. Additional mixture evaluations (i.e. coating, compactability, moisture sensitivity and rutting resistance) should then be conducted using lab- or plant-produced WMA.

Thirteen WMA mixes were evaluated in NCHRP 9-47A, all of which were designed as HMA and produced using WMA processes or additives. Mix design verifications were performed on 10 of these mixes, using the respective WMA technology and the procedures given in the appendix. Field-measured gradations were matched as closely as possible and optimum asphalt contents were also verified for the HMA control sections. Using this approach, the optimum asphalt contents for most of the WMA mix designs were significantly less than for the companion HMA. The average decrease in the optimum asphalt content was 0.27 percent.

—Continued on Pg. 7

—Continued from Pg. 6

While there are possible justifications for lower asphalt contents in WMA, none were confirmed by the NCHRP 9-47A research. For example,

- *Binder absorption:* For both plant- and lab-produced mixes in NCHRP 9-47A, binder absorption was an average of 0.11 and 0.17 percent lower, respectively, for WMA compared to HMA with the same materials. However, tests on cores after one and two years indicate that the differences in binder absorption were practically nil, suggesting that further absorption occurs over time. This does not support a reduction in asphalt content for WMA mixes due to binder absorption.
- *Pavement densification:* Previous studies indicate that the majority of pavement densification under traffic occurs within one to two years after construction. If WMA mixes experience excessive densification in the wheel paths, this could justify lower asphalt contents. However, the average densities for the one- and two-year cores were similar or lower for the WMA sections compared to the corresponding HMA, indicating that the WMA pavements are not over-densifying under traffic.
- *Rutting potential:* As shown in Table 1, the one- and two-year rut depths are slight and nearly equivalent for both WMA and HMA field test sections observed in NCHRP 9-47A. Based on field rutting performance, reducing the asphalt content of WMA mixes is not warranted.
- *Interaction with compactability:* For each WMA mix, compactability ratios were determined at the optimum asphalt content, which was an average of 0.27 percent less than the HMA counterpart. A poor relationship existed between compactability ratios and in-place density. Four mixes were tested again at the field-measured optimum asphalt content—as expected, the compactability ratio increased when the asphalt content decreased (by 0.74 and 0.90 percent) and decreased for a 0.39 percent increase in asphalt content. The fourth sample had a 0.17 percent increase in asphalt content with a virtually unchanged compactability ratio. This indicates that compactability is indeed dependent on asphalt content. Thus, a decrease in asphalt content could negate the compaction benefits associated with WMA.

Mixture Evaluations

As discussed in section 8.4 of the appendix, samples for evaluating moisture sensitivity should be prepared using the WMA additive or process. For foaming technologies, this procedure should include the option of using mix produced during a trial run at an asphalt plant in lieu of lab-produced mix.

Section 8.5 describes evaluating rutting resistance of WMA using the flow number test (AASHTO TP 79). Based on WMA field rutting performance to date, additional testing beyond what is required for HMA seems unwarranted. Thus, NCHRP 9-47A recommends that the minimum flow number requirements given in section 8.5 be removed for traffic levels less than 30 million ESALs.

Asphalt Forum

NCAT invites your comments and questions, which may be submitted to Courtney Jones at courtneyj@centurytel.net. Questions and responses are published in each issue of *Asphalt Technology News* with editing for consistency and space limitations.

Jerry Geib, Minnesota DOT

Almost all of the WMA we see is produced by the water injection method, with a minimal decrease in plant operating temperatures.

Joe Schroer, Missouri DOT

Does anyone have special considerations in their mix design requirements for high water absorption (2-4 percent) aggregates?

Ray Brown, NCAT

Where does your agency take asphalt mix samples for QA (out of truck? auger? behind paver?), and why do you take them at this location?

Don Watson, NCAT

Has anyone conducted a comparison between plant and roadway sampling and testing variability? If so, is a report available?

Does your agency have data or reports that document the effect of existing pavement condition and surface preparation on thin overlay performance? Is there any explanation for the wide range in performance of thin asphalt overlays?

Asphalt Forum Responses

The following responses have been received to questions shared in the Fall 2012 Asphalt Forum.

1. When selecting candidates for re-surfacing projects, what does your state find the most useful (pavement management data, indices, tests, procedures, etc.) for a healthy resurfacing program? (Mark Woods, Tennessee DOT)

Michael Stanford, Colorado DOT
CDOT uses pavement management data.

Jim Musselman, Florida DOT
FDOT has an extensive pavement management program and relies primarily on pavement management data (specifically ride, rut and crack ratings) to prioritize resurfacing projects.

Kevin Kennedy, Michigan DOT
Pavement management data and historical pavement performance are important.

Jerry Geib, Minnesota DOT
We consider pavement management data, the amount of maintenance patching work done, past performance and public input when selecting re-surfacing projects. Project scoping is now being done five years ahead of the letting, and projects are placed in the State Transportation Improvement Program (STIP) four years ahead of the letting.

Joe Schroer, Missouri DOT
Missouri uses pavement management data to initially prioritize candidate resurfacing projects, but final treatment types and project scheduling are dictated by results from field visits and coring.

Charlie Pan, Nevada DOT
Nevada uses pavement management data and field review.

Seyed Tabib, Ontario Ministry of Transportation
We look at the following:

- The desired design life of the treatment.
- The structural adequacy/capacity for the design period to assess if resurfacing is sufficient or if there is a need for an increase in structural requirement.
- Whether resurfacing is a suitable rehabilitation strategy based on the distresses present.

2. Have you allowed WMA to extend your paving season? If so, can you cite a specific resource or research paper that the decision or limits were based on? If temperature or calendar limits were changed, what are they now? (Ken Hobson, Oklahoma DOT)

Michael Stanford, Colorado DOT
Yes – while using WMA, contractors are allowed to pave as long as they are able to achieve the required compaction.

Jim Musselman, Florida DOT
Yes, FDOT reduces the minimum required ambient air temperature by 5°F when WMA is used. This number was set by engineering judgment and was not based on any specific research.

Kevin Kennedy, Michigan DOT
We have not allowed warm mix to extend the paving season.

Jerry Geib, Minnesota DOT
No. Our specification has weather and paving date restrictions. These can be waived, but the contractor must get density.

Charlie Pan, Nevada DOT
No.

Eric Biehl, Ohio DOT
We currently use only foamed WMA, with a 30°F drop in mixing and compaction temperatures. Contractors in Ohio primarily use WMA as a compaction aid, and we have not seen an extended season due to this.

Seyed Tabib, Ontario Ministry of Transportation
MTO is going to drop the ambient paving temperature for selected contracts. For premium surface course mix, our specification requires minimum 12oC ambient temperature. We are going to drop this temperature down to 7oC for selected contracts using WMA. We will review compaction data for those trial contracts and decide accordingly, in partnership with our hot mix asphalt industry. We did not come across any research paper in this regard. We need to examine this on our own contracts.

Mark Woods, Tennessee DOT
While we would consider it an encouraging factor if listed on a cold weather paving request, we have not had any requests thus far that include WMA.

3. We would like information from other DOTs about tack coats you have used and resulting bond strengths. (Bill King, Lousiana DOT)

Michael Stanford, Colorado DOT
This is a current research project for CDOT.

Jim Musselman, Florida DOT
FDOT typically uses emulsified asphalts for tack. RS-1 and NTSS-1hm are most commonly used. We have found that bond strengths can easily reach 100 psi if they are tacked properly. FDOT has a developmental specification for bond strength, and the required minimum value is 50 psi.

—Continued on Pg. 9

—Continued from Pg. 8

Kevin Kennedy, Michigan DOT
We specify SS-1h or CSS-1h. There are discussions going on currently with industry regarding bond coats (materials and testing for bond strength).

Jerry Geib, Minnesota DOT
We mainly use CSS-1h. We will begin a research project to look at bond strength in 2013.

Charlie Pan, Nevada DOT
We normally use SS-1h, with no tests for bond strength.

Eric Biehl, Ohio DOT
We currently allow SS-1h, SS-1, CSS-1h, CSS-1, RS-1, an SBR-modified tack coat and trackless tack per specification and plan note. However, the most common tack coat is SS-1h, followed by trackless tack. We have not looked into bond strength besides what we know from NCHRP Project 9-40.

Mark Woods, Tennessee DOT
The TDOT central laboratory has recently acquired a guillotine-type shear testing device for evaluating bond strength, but no major results have been generated thus far.

4. Does your agency assign a factor less than 100 percent for reclaimed asphalt pavement (RAP) binder contribution to the mix? How was the factor determined? Are there research reports on your experience that can be referenced? (Don Watson, NCAT)

Michael Stanford, Colorado DOT
We currently assign a factor of 100 percent.

Jim Musselman, Florida DOT
No.

Kevin Kennedy, Michigan DOT
We have a tiered system for RAP usage. Higher usage requires bumping the low end binder grade and in some cases developing a blending chart.

Jerry Geib, Minnesota DOT
No.

Charlie Pan, Nevada DOT
No.

Eric Biehl, Ohio DOT
No, we do not use a factor other than 100 percent.

Seyed Tabib, Ontario Ministry of Transportation
We do not assign a factor to the recycled asphalt cement contribution to the mix.

Mark Woods, Tennessee DOT
TDOT currently considers RAP as contributing 100 percent of its binder.

5. What are your highest priority research needs in the area of pavement preservation? (Don Watson, NCAT)

Michael Stanford, Colorado DOT
Our greatest research needs for pavement preservation are in the areas of HMA layer bond strength testing and best management practices for crack, seal and fill.

Jim Musselman, Florida DOT
The most critical research needs for Florida are related to raveling in open graded friction courses and top down cracking.

Kevin Kennedy, Michigan DOT
The greatest research needs for Michigan are testing protocol for ultra-thin HMA overlays, reducing reflective cracking in HMA overlays, and longitudinal joint performance.

Jerry Geib, Minnesota DOT
Minnesota's most critical need is cost effective rehabilitation solutions for aging pavements. We also need more emphasis on the details of paving workmanship (i.e. temperature and material segregation, longitudinal joint density, uniform tack coat application, etc).

Charlie Pan, Nevada DOT
Long-term performance and non-destructive testing are our greatest research needs.

Seyed Tabib, Ontario Ministry of Transportation
Our greatest research need in the area of pavement preservation is performance improvement and life cycle for treatments for various pavement conditions.

Mark Woods, Tennessee DOT
We would like to see a method (e.g. fog seal, small NMAS OGFC or PEM overlay, etc) for extending the service life of in-place porous mixtures.

6. Has anyone used micro-milling to restore surface texture and friction and left it as the final riding surface? How was the quality of the work measured? Describe your results. (Don Watson, NCAT)

Michael Stanford, Colorado DOT
Not currently.

Jim Musselman, Florida DOT
No, FDOT does not allow a milled surface to be the final surface.

Kevin Kennedy, Michigan DOT
We allow the use of micro-milling for ride quality corrections.

—Continued on Pg. 10

—Continued from Pg. 9

This is new to our specification, so we have limited experience. Thus far, the quality has been good.

Jerry Geib, Minnesota DOT
No. We are planning to try micro-milling in 2013, but all milling will receive a surface treatment.

Charlie Pan, Nevada DOT
We have used micro-milling only for smoothness, and we have left it as the final riding surface.

Eric Biehl, Ohio DOT
We have done micro-milling in areas where skid resistance was low for sharp turns such as ramps. The texture improved the skid resistance. We are working on a micro-milling spec.

Seyed Tabib, Ontario Ministry of Transportation
In Ontario, we recently had one job where the smoothness testing identified a few localized rough areas, and the contractor proposed to use micro-milling instead of diamond grinding. They did a demonstration in their yard in our presence, and we allowed them to use micro-milling on the highway for smoothness correction on the surface lift. They partially completed the micro-milling and had to shut down for the winter. When they come back in the spring to finish, we will re-measure for smoothness. The final surface texture appeared to be similar to diamond grinding.

Mark Woods, Tennessee DOT
We have used micro-milling on a few small projects. Work was monitored via high-speed inertial profiler, and it was reconfirmed that slow milling machine speed, proper electronic grade control settings, and similar milling best practices were most important.

7. Tack coat bond strength has been an item of national research for the last few years. What is your agency doing differently today to improve tack coat bond strength? (Don Watson, NCAT)

Michael Stanford, Colorado DOT
We now require verification of the application rate, as well as continued visual inspection of the uniformity of the tack coat.

Jim Musselman, Florida DOT
FDOT has a developmental performance specification related to bond strength. It allows the contractor to select their tack material and application rates, and it also eliminates inspection requirements for the agency. The required bond strength is a minimum of 50 psi. It has been used on one pilot project so far.

Kevin Kennedy, Michigan DOT
This is currently a discussion item, with industry being addressed by our HMA Technical Committee.

Jerry Geib, Minnesota DOT
Our tack specification has been updated to add penalties and require distributor calibration. In the past, tack application has been poorly done – not uniform.

Eric Biehl, Ohio DOT
Ohio ensures that tack coat applications are uniform and remain there through the paving process. We do not have requirements for bond strength at this time, but we may add this option in our proposed trackless tack specification.

Specification Corner

Colorado

CDOT has developed two new asphalt mix gradations: a 3/8-in. mix (ST) and a #4 mix (SF). These mix gradations will be specified when thin lift overlays are deemed the most appropriate surface treatment. This is a revision of Section 703 – Aggregates for Hot Mix Asphalt, of the CDOT Specification.

We are currently evaluating the need to revise our RAP specification, to be based on percent of asphalt binder replaced, instead of the current specification that is based on percent RAP in the mix. This revision is approaching the final approval process – if approved it could be fully implemented by late spring of 2013.

Florida

In July 2013, FDOT will implement a new PG 76-22 binder that will require the use of a minimum of 7 percent ground tire rubber (GTR). This binder will be required to meet all of the requirements for a PG 76-22 binder, with the exception of solubility. Additional requirements include a separation test and the Multiple Stress Creep Recovery (MSCR) test. The binder can be made exclusively with GTR or a blend of GTR and polymer. This new binder will be called PG 76-22 (ARB). FDOT will continue to use an SBS polymer-modified binder – PG 76-22 (PMA) on all high traffic volume projects and any projects with a history of rutting.

FDOT will also adopt the MSCR test (J_{nr} and % Recovery) for all modified binders beginning in July 2013.

Michigan

Michigan implemented a longitudinal joint specification in 2012. We are currently reviewing the data and plan to make further revisions. The intent is to improve the quality and durability of longitudinal joints.

Michigan has increased the allowable use of RAP.

Michigan is now allowing the use of a fine-toothed mill for ride quality corrections.

—Continued on Pg. 11

—*Continued from Pg. 10*

Michigan has a crumb rubber pilot project scheduled for 2013 (contractor option of terminal blend or wet process).

Minnesota

We have had good results with our limited use of stone matrix asphalt (SMA) and Ultra Thin Bonded Wearing Course. We would like to use more of these mixes on future projects.

The Pave-IR bar will also be required on more projects. We have found this to be a great tool to assist the contractor in improving their operations and reducing thermal segregation.

Current MnDOT specifications use a binder replacement requirement rather than a maximum percentage of recycled asphalt pavement (RAP).

Plant recordation results are taken every 20 minutes, and all readings of the plant operation are recorded.

Missouri

For 2013, we plan to increase tack coat rates to levels consistent with NCHRP Report 712. Missouri began investigating delamination of pavement layers shortly before release of the report. It was discovered that as tack materials transitioned from cutbacks to emulsions, the specification rates were not adjusted to account for the residual asphalt content of emulsions.

An adjustment to the bulk specific gravity specification is also planned for 2013. When using AASHTO T 166 for the bulk specific gravity of cores with high air voids, Missouri is disallowing the use of AASHTO T 275, bulk gravity using paraffin-coated specimens. It was discovered that this method can falsely inflate the bulk specific gravity results by wax permeating internal voids. Vacuum sealing, AASHTO T 331, and Parafilm, ASTM D1188, will be the allowed methods when required by T 166.

Nevada

We have added permissive language to allow using warm-mix asphalt (WMA). Plant mix bituminous surface may be mixed and placed at lower temperatures than normally specified when using one of the technologies covered by the term WMA. If desired, WMA may be proposed for placement of dense graded plant mix bituminous surface.

Ohio

We have recently allowed Elvaloy® and will soon be allowing ground tire rubber (GTR) as other options to SBS and SB polymers for pre-blending for modified PG binders, based on successful past projects.

We have recently allowed the production of PG 64-28 binder using polyphosphoric acid (PPA) rather than polymer modification. A truly neat PG 64-28 binder is hard to produce and not refined locally. Since we only use this binder for intermediate courses, there was no justification to force producers to use only polymers. There is still a PG 64-28 polymer-modified specification with PG plus testing for those producers who do not wish to use PPA. There have been no reports of issues with the PG 64-28 PPA-modified binder in the field.

We are planning to create a specification for a highly polymerized PG binder, around 7-8 percent SBS, for high stress areas, pavement reductions and other applications. We currently have a PG 76-22M, which contains roughly 4 percent SBS.

We are currently working on a specification for trackless tack products to replace existing plan notes. Trackless tack usage has increased over the past few years, so a specification is needed.

In the past, we have determined theoretical maximum specific gravity using the saturated surface-dry (SSD) method on all mixes. In a recent change to a specification, SSD will now only be performed on mixes that retain more than 0.18 percent water based on dry weight. This change was due to the majority of mixes retaining very little water in the SSD condition, so the maximum specific gravity was barely affected. Other benefits are less time for testing and more immediate results in the field as well as a potential one-tenth increase in percent binder in the mix. We also made the maximum specific gravity procedure specific to one procedure/equipment to keep contractors and DOT consistent.

Ontario

Ministry of Transportation of Ontario (MTO), in partnership with Ontario's hot mix asphalt industry, has developed a permissive specification for using warm-mix asphalt (WMA). The specification allows contractors to use WMA in lieu of HMA. WMA mix design should follow AASHTO R35 Appendix X2.

Since 2012, MTO has fully switched to using high-speed inertial profilers for acceptance of asphalt pavements. The specification requires that pavement smoothness be measured using the QA profiler. Pay factors are identified based on IRI for each 100-m sublot. The overall pay factor will be an average of all the sublot pay factors. Localized roughness is identified using the Smoothness Assurance Module of ProVAL 3.3. Localized roughness areas are either subject to payment reduction or to repair, based on their severity.

Based on concerns with premature cracking of asphalt pavements, MTO requires all PGAC grades to have an Ash Content of less than 1 percent, according to a MTO laboratory testing standard, LS-227. Additionally, PGAC grades, with the exclusion of PG 58-28 and 52-34, are required to meet specific testing criteria for LS-299 (Double Edge Notched Tension test) and Multiple Stress Creep Recovery testing (Non-recoverable creep compliance at 3.2 -J_{nr}3.2 and average percent recovery -R3.2). Low temperature limiting grade and grade loss determined according to MTO LS-308 are conducted for information purposes.

MTO, in consultation with the industry, is developing a performance-based specification for crack sealing in hot mix asphalt pavements. It has a two-year warranty period on the performance of the sealed cracks. This specification is near completion and should allow the contractor to select rout geometry for the Rout & Seal option, in addition to the Clean & Seal option available. It should also allow the contractor to select the type of hot-poured rubberized asphalt crack sealant.

MTO is developing a performance-based specification for asphalt pavements based on a 5-year warranty period.

Tennessee

We have added a trackless tack to the list of available options for use as tack coat. Specified tack coat rates for non-milled surfaces were changed from a maximum of 0.05 gal/yd^2 "residual bitumen" to 0.05-0.10 gal/yd^2 applied emulsion. Specified tack coat rates for milled surfaces were changed from a maximum of 0.20 gal/yd^2 "residual bitumen" to 0.08-0.12 gal/yd^2 applied emulsion.

Improving the Durability of Open-Graded Asphalt Mixtures

Donald Watson, Lead Research Engineer, NCAT

The use of Open-Graded Friction Courses (OGFC), sometimes referred to as porous friction courses, has been somewhat limited due to problems with mixture durability. Because of the high porosity of the layer which enables water to be channeled through the mix rather than across the surface, this mix tends to age more rapidly than dense-graded mixtures. Therefore, OGFC layers are more prone to raveling and stripping in the wet-freeze climatic zones. In a 1998 survey conducted by NCAT, it was found that 78 percent of the 43 states that responded reported good to excellent performance of OGFC in terms of durability. However, 17 percent of the respondents indicated they were typically getting less than 6 years average service life from these mixtures.

The major problem with service life in years past was related to binder draindown. When "rich" spots were observed with asphalt cement flushing to the surface, a common perception was that the binder content was too high, or that the mixture was too hot during production and placement, causing draindown. As a result, engineers reduced the asphalt content and/or reduced mix temperature. It was common to produce these mixtures at 220-230 F. It is now known that both of these responses were the wrong approach, and it is no surprise that the layers failed with premature raveling. In reducing asphalt content, the durability or service life of the mix was reduced; and by reducing production temperature, the asphalt/aggregate bond was reduced because internal moisture was not completely removed from the aggregate particles.

However, there are many safety benefits of OGFC, such as: reduced splash and spray during rain, reduced potential for hydroplaning, reduced headlight glare, improved visibility of traffic stripes during rain, and improved wet weather friction. As a result of the safety benefits from use of this mix, there have been several research efforts in the last 15 years to improve the longevity of OGFC mixtures. The research has been concentrated in the areas of materials, mix design procedure, and construction.

Several improvements to OGFC come from ideas borrowed from Stone Matrix Asphalt (SMA), originally developed in Europe for resistance to studded tire wear. From research and implementation of SMA technology, it was learned that draindown can be eliminated by introducing fiber stabilizers into the mixture. This allows higher asphalt contents to be used. The use of modified asphalt also resulted in improvement as mixtures were able to be heated to production temperatures common for dense-graded mixtures.

Table 1. Aggregate Quality for SMA/OGFC

Aggregate Property	Recommended Value
L.A. Abrasion	<30 *
Flat and Elongated Particles	<20% at 3:1 ratio; <5% at 5:1 ratio
Fractured Faces	100% one face; >90% two or more faces

*Aggregates with higher abrasion values have been used successfully, but may result in excessive breakdown in laboratory testing.

Aggregate quality for OGFC mixtures has been improved because many agencies use the same high standards as specified for SMA mixtures. The criteria of Table 1 are recommended values for SMA and OGFC aggregate properties.

Ten percent maximum flat and elongated particles based on the 5:1 ratio of length to thickness were common in the past, so the reduction to 5 percent flat and elongated at 5:1 is a considerable improvement. If the maximum of 20 percent at a 3:1 ratio is used as well, the aggregates produced will be more cubical and less likely to fracture during production and placement. Therefore, the number of uncoated, fractured faces exposed during construction will be reduced.

Since there is very little fine aggregate in OGFC mixtures, the cohesiveness of the mixture almost totally depends on the binder content and binder properties. Modifiers such as styrene-butadiene-styrene (SBS), styrene-butadiene-rubber (SBR), and ground tire rubber (GTR) have improved binder properties. These modifiers have increased the viscosity of the binder film to help reduce draindown potential; but more importantly, they have allowed production at higher temperatures which effectively reduces aggregate moisture content. The modifiers also add a degree of resiliency to the binders that was not present in the past. Research at NCAT has shown that the use of modifiers has reduced the wear loss, or potential for raveling, in OGFC mixtures.

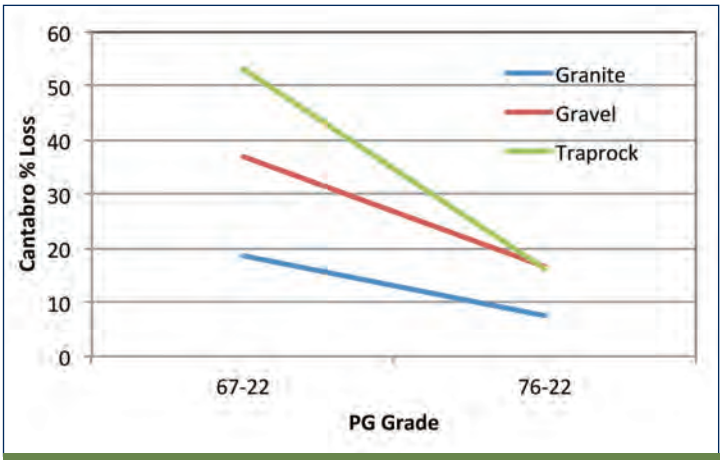

Figure 1. Effect of Modified Asphalt on Cantabro Wear Loss

There are several mix design methods used for optimizing the OGFC mix. However, some of the earlier design methods were primarily for determining optimum asphalt content based on oil absorption by the aggregate particles. The procedures lacked any laboratory performance tests to simulate how well the mixtures would perform under typical pavement conditions. An NCAT procedure, revised in 2005, is one of the first procedures to incorporate a modified version of AASHTO T 283 to simulate

—Continued on Pg. 13

—Continued on Pg. 12

the potential for moisture susceptibility, a drain-down test to measure the effectiveness of stabilizing fibers, a wear test to simulate potential for raveling, a permeability test to measure the water flow properties, and adopting the Superpave Gyratory for compacting laboratory samples.

AASHTO T 283 was modified for OGFC moisture susceptibility testing. Due to the amount of air voids in the mixture, the sample is vacuum saturated for 10 minutes. Saturation is not calculated due to the difficulty in obtaining accurate saturated surface dry measurements. In addition, the sample is also kept submerged during the freeze-thaw process; otherwise, water from the internal void structure would drain out. Some research also considered multiple freeze-thaw cycles to evaluate susceptibility to moisture damage. NCAT tested samples from three aggregate types using one, three, and five freeze-thaw cycles and found that increasing the number of cycles did not appreciably affect the tensile strength of the mix (Figure 2). The very low R-squared values indicate that there is little effect of the number of freeze-thaw cycles on tensile strength. In regard to moisture susceptibility, more documentation is needed to determine if a correlation between laboratory performance and field performance can be established.

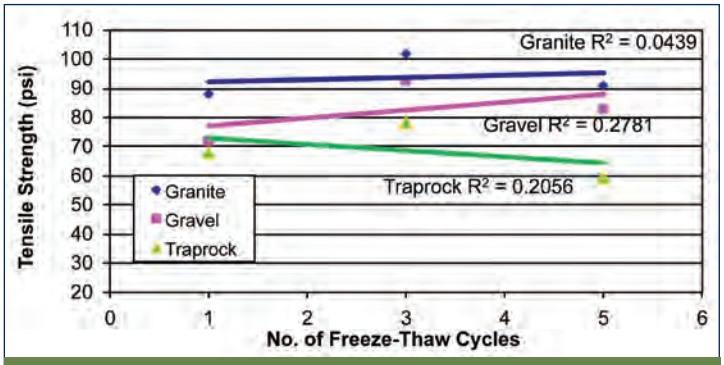

Figure 2. Effect of Freeze-Thaw Cycles on Tensile Strength

NCAT also considered the effect of fiber stabilizing additives to reduce potential for draindown. It was found that stabilizing fibers were significantly effective at reducing draindown (Figure 3) even when a polymer-modified binder was used.

The Cantabro test is a Spanish test method to evaluate the wear potential of an asphalt mixture. It is especially useful in the OGFC mix design procedure since wear, or raveling, is one of the primary forms of distress. The procedure uses the L.A. abrasion drum without steel balls and each compacted specimen is allowed to tumble inside the drum for 300 revolutions. Afterward, the amount of specimen wear is determined. The Cantabro procedure has verified that increasing asphalt content can improve the resistance to raveling (Figure 4). For this design, 150 mm diameter samples were compacted with 50 gyrations using a Superpave gyratory compactor to a standard gyratory height of 115 mm. A modified asphalt binder was used in this mix design, and a maximum loss of 10 percent was used to determine optimum asphalt content for the mix. At 6.0 percent asphalt

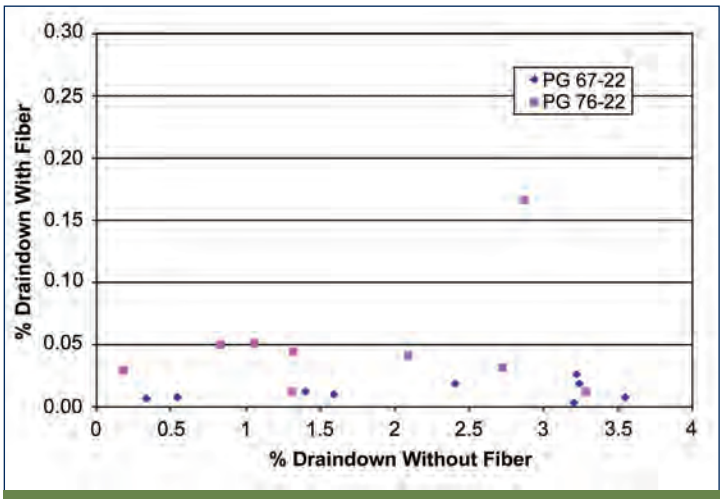

Figure 3. Percent Draindown With and Without Fiber

binder content, the air voids for this mixture still exceeded 20 percent, which is within the range of 18-22 percent air voids needed to provide adequate water drainage.

There are several possible causes for raveling of OGFC mixtures, such as low asphalt binder content, spread rates that are too low (thin layers), and lack of adequate tack coat. Yet a previous NCAT survey showed that eight percent of responding states did not use tack coat at all, and nearly half (46 percent) of responding states used less than 0.06 gal/yd² which is comparable to applications for dense-graded mixtures. Several research studies are reevaluating the importance of obtaining sufficient tack coat to properly bond the OGFC layer with the existing pavement. A variety of tack coat materials are being studied so that not only is tack quantity considered, but the type of tack as well. Modified tack coats at higher application rates are believed to be needed, and some of the materials being evaluated currently provide a uniform coverage at an application rate around 0.15 gal/yd².

—Continued on Pg. 14

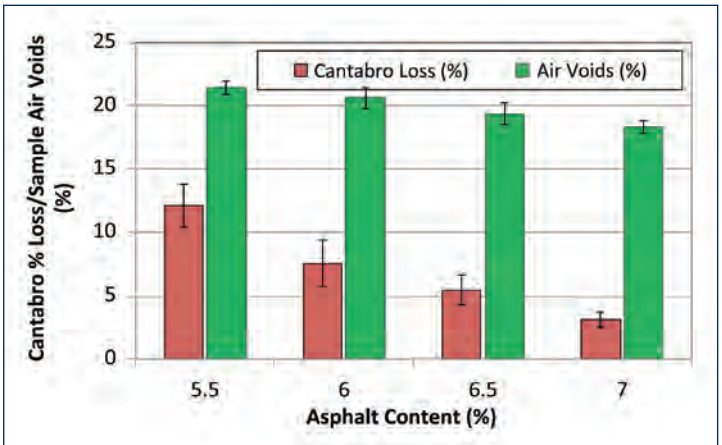

Figure 4. Effect of Asphalt Content on Cantabro Loss and Air Voids

—Continued from Pg. 13

Figure 5. Poor Tack Application Prior to OGFC Placement

During construction, it is important that more attention be given to proper application of tack coats. The tack coat application in Figure 5 is far too often typical of the quality of tack operations and does not provide the quantity or the coverage needed to create a suitable bond between layers.

OGFC sections at the NCAT Pavement Test Track have also verified that thicker layers of OGFC could improve durability. In 2006, a double layer OGFC section was placed, in which 1.25 inches of a coarse OGFC was overlaid with a 0.63 inch thick layer of smaller NMAS OGFC for a total thickness of 1.88 inches. The section was still performing well after 20 million Equivalent Single Axle Loads (ESALs) when the section was removed for another experiment. In 2009, the same OGFC mixture was placed on sections S8 and N2. The difference between the sections was that the OGFC in section N2 was placed at 0.8 inches (20 mm) thick and S8 was placed at 1.3 inches (32 mm) thick. The performance of the thicker section with regard to splash and spray and permeability was much better than the thinner layer. S8 performed so well, it is regarded as the control mix by which to evaluate other OGFC mixtures placed in the 2012 research cycle of the test track.

These results have led to a conclusion that durability of OGFC layers may be improved by increasing the layer thickness, and a Michigan study of OGFC performance recommended the mix not be placed less than 1.25 inches (32 mm) thick for drainage purposes. As shown in Table 2, a minimum thickness/NMAS ratio of 2.5 is recommended for OGFC mixtures. However, there is a need for additional research to validate the thickness/NMAS ratio for open-graded mixtures as was done for dense-graded mixes in NCHRP 9-27.

TABLE 2. Recommended Application Rates for OGFC Mixtures

NMAS (mm)	Minimum Thickness, in.	Typical Spread Rate, lbs/yd² (kg/m²)
19	2.0 (48 mm)	220 (119)
12.5	1.25 (32 mm)	138 (75)
9.5	1.0 (24 mm)	110 (60)
4.75	0.5 (12 mm)	55 (30)

Today's OGFC is a vast improvement over the materials and design methods used in the past. Durability is improved with the addition of fiber stabilizers and modified asphalt binders to eliminate previous draindown problems and the increase in production temperatures to sufficiently dry out internal aggregate moisture and improve cohesiveness of the mixture. Increasing the quantity and quality of tack applications will also provide a better bond at the interface of the OGFC and existing pavement layers. NCAT continues to support sponsors who wish to find ways to improve the durability and functionality of OGFC mixtures in order to provide a safer, longer-lasting driving environment for the general public.

Completed LR 159 Project

NCAT offers a variety of training opportunities to fit your needs. To register for a class or for more information, please visit our website: www.ncat.us or call Don Watson at 334.844.7306.

New Course Focuses on Sustainable Pavements

A new graduate-level course, Special Topics in Civil Engineering: Sustainable Pavements, is being offered during the spring 2013 semester through Auburn University's Samuel Ginn College of Engineering. Lead instructor Dr. Richard Willis, an assistant research professor with NCAT, is providing students with a real-world understanding of how to design and build pavements sustainably.

"We sometimes look at environment and economics as being mutually exclusive, but this class will help students make decisions for pavements that will be environmentally friendly, economically sound and socially equitable," says Willis.

The course, which was developed under a grant provided by the Southeastern Transportation Research, Innovation, Development and Education Center, defines the different facets of sustainability and describes how sustainability can be quantified. Students are learning how to improve the sustainability of our pavement infrastructure through material selection as well as construction and maintenance practices. Additionally, students will gain an understanding of how pavement material properties affect vehicle fuel economy, an important facet of sustainability.

Willis is assisted by other NCAT engineers that are teaching sections of the course related to their individual areas of expertise. Dr. Carolina Rodezno is covering the use of warm-mix asphalt (WMA) and ground tire rubber (GTR), while Don Watson is teaching sessions on porous pavements and in-place recycling.

The 3-credit hour course is available both on-campus and through the convenient option of distance learning. NCAT also plans to use the course material for conducting future workshops throughout the Southeast.

Participants at an Asphalt Technology class held in Denver, Colorado. This training course was conducted as a joint effort between the Colorado Asphalt Pavement Association and Colorado DOT.

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY
735 Extension Loop, Auburn, AL 36849-7350

Nonprofit Org.
U.S. Postage
PAID
Permit #9
Auburn, AL 36849

National Center for Asphalt Technology,
277 Technology Parkway, Auburn, Alabama 36830-0550
Phone: 334.844.NCAT (6228) Fax: 334.844.6248

Randy West, Director, NCAT
Morgan Stashick, Editor, College of Engineering
Courtney Jones, Editor, NCAT

ASPHALT TECHNOLOGY NEWS (Library of Congress Catalog No. ISSN 1083-687X) is published by the National Center for Asphalt Technology (NCAT) of Auburn University. Its purpose is to facilitate the exchange and dissemination of information about hot mix asphalt technology, trends, developments and concerns. Opinions expressed in this publication by contributors and editors, the mention of brand names, the inclusion of research results, and the interpretation of those results do not imply endorsement or reflect the official positions or policies of NCAT or Auburn University.

Participants at an Asphalt Technology course sponsored by Caterpillar, Inc. Engineers, product specialists, and marketing personnel from Caterpillar and Weller attended this class held at NCAT.