

Spring 2014
Volume 26, Number 1

Asphalt Technology News

In This Issue

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Test Track Sections Evaluate Use of Cold Central-Plant Recycling for High-Volume Roads

Cold central-plant recycling (CCPR) is gaining interest as a cost-effective alternative for base layers in pavement reconstruction. CCPR combines reclaimed asphalt pavement (RAP) with foamed or emulsified asphalt in a central production plant without the application of heat. The resulting material is handled much like asphalt mixtures during pavement construction; the material is placed with conventional pavers and compacted with traditional rollers.

The CCPR process provides an opportunity to use excessive RAP stockpiles in a beneficial application. Although the CCPR material is similar to that produced using cold in-place recycling (CIR), CCPR offers more opportunities for quality control during production and can also be used in areas where CIR would be impractical. CCPR has been used more often in the western U.S., including California and Nevada, where it has been used successfully on city streets and other low-volume applications. While the technique is not new, advances in binder materials, RAP processing and cold mix production have made CCPR an increasingly attractive choice for producing an economical material for a long-lasting pavement.

I-81 In-place pavement recycling project (Photo by Tom Saunders, VDOT)

Virginia's Experience on I-81

In 2011, the Virginia Department of Transportation (VDOT) placed a CCPR base on a 3.66-mile section of I-81 in Augusta County. This high-profile project combined three recycling processes—CCPR, CIR and full-depth reclamation (FDR)—for the first time ever on one Interstate highway project.

Significant deterioration of the existing underlying pavement structure warranted complete reconstruction of the right-hand lane. The existing asphalt was milled, leaving just one inch of asphalt that was processed using FDR with the existing aggregate base and upper portion of the subgrade. The RAP from milling was then mixed with foamed asphalt and Portland cement in an onsite CCPR mobile plant and placed in a 6-inch layer using conventional paving equipment. The CCPR base was covered with 6 inches of conventional asphalt overlay. In the left-hand passing lane, the existing pavement structure was in better condition. Since no reconstruction of the aggregate base was needed, this lane was recycled in-place using the CIR method to a depth of five inches (following a 2-inch pre-mill operation) and topped with 4 inches of conventional asphalt mix.

Using these time-saving onsite recycling methods allowed VDOT to employ a unique traffic-management plan incorporating a single lane closure and detour for passenger cars. If conventional construction techniques had been used, the reconstruction project could have required building another lane to accommodate

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work-zone traffic and could have taken years rather than months to complete. Recycling not only saved time on this project, but also huge quantities of new materials, as well as the fuel consumed in transporting them. By using onsite recycling techniques such as CCPR, CIR and FDR, this $7.64 million project allowed the repair of deep failures at significant taxpayer savings and with substantially less construction-related traffic delays.

CCPR Research at NCAT Pavement Test Track

VDOT is sponsoring three sections on the 2012 NCAT Pavement Test Track research cycle to further evaluate the use of CCPR base material for high-volume applications. In order to determine the structural contribution of CCPR base in pavement design, all three sections are instrumented for recording structural response under loading. Sections N3 and N4 are comparing the overlay thickness of conventional asphalt mixes (6 inches vs. 4 inches, respectively) when placed over a CCPR base. Section S12 compares FDR with the conventional base and subgrade construction used in N4.

Cross-sections of the three VDOT-sponsored test sections are pictured in Figure 1. All three were built on the same subgrade material. Sections N3 and N4 were built on a crushed granite base course, while S12 featured a stabilized base course that was constructed using FDR, treated with cement and compacted in place. A CCPR layer was constructed above the base layers. Superpave mixtures were placed on top of the CCPR layer and each section was surfaced with stone matrix asphalt (SMA). Section N3 had the thickest asphalt concrete (AC) layers (6 inches total), while the other two sections used approximately 4 inches of AC above the CCPR. Strain gauges and temperature probes were embedded during construction. Although other gauges were also installed, the focus here is solely on the horizontal strain measurements as an indicator of how bottom-up cracking may develop. The temperature probes monitor mid-depth pavement temperature crucial to understanding the environmental effects on these pavements.

Figure 2 Mobile cold recycling mixing plant used during Test Track construction

Production of the CCPR base at the NCAT Pavement Test Track is shown in Figure 2. The RAP was first processed to a top size of one-half inch and then mixed with 2 percent foamed asphalt binder and 1 percent Portland cement in an onsite mobile cold recycling plant. The CCPR material was placed in a single lift and compacted to a target layer thickness of 5 inches using conventional paving equipment.

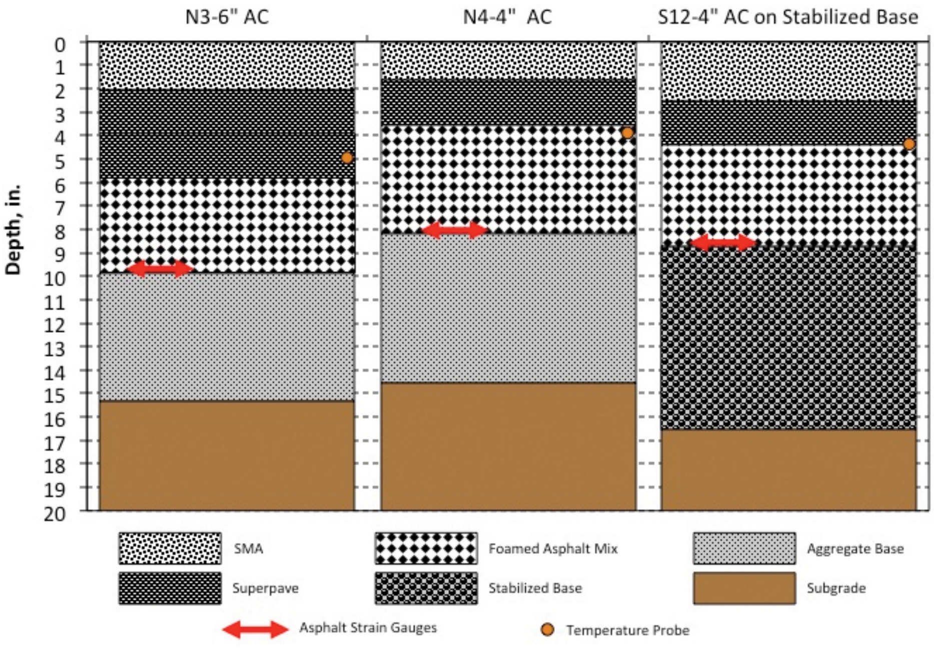

Figure 1 Cross-section of VDOT sections at 2012 NCAT Pavement Test Track

A fleet of heavily loaded trucks circles the track 16 hours a day, five days a week, resulting in 10 million equivalent single axle loads (ESALs) applied over a two-year period. The sections have been subjected to weekly structural response monitoring since the onset of trafficking in October 2012. Figure 3 shows the horizontal strain response in each section through January 2014. As expected, the lowest strain levels were measured in S12 where the stabilized base course contributes to less overall bending of the AC layers. The highest strain levels were observed in N4, which had the thinnest AC over the conventional aggregate base layer, while section N3—with 6 inches of AC—experienced intermediate strain levels. Also of note is the general insensitivity of S12 to the change in season and temperature. While N3 and N4 both experienced significantly higher strain levels during the warm summer months and lower strains during cooler periods, S12 did not—presumably due to the stabilized base course not changing appreciably with

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temperature. Since cracking has not been observed in any of these sections, it remains to be seen what effect the various strain levels have on cracking performance. At this point, the sections are all performing well.

In addition to monitoring the strain response, the sections are tested using the falling weight deflectometer (FWD) several times per month. This testing helps determine the backcalculated modulus of the AC. Figure 4 shows the backcalculated AC modulus of each section at a standard reference temperature of 68°F. The scatter in the data on particular test dates represents normal spatial variation throughout each section. Linear trendlines fit to each data set show that the moduli are generally holding steady over time. This is an indicator of structural health, as one would expect a drop in modulus, or highly erratic modulus values, if damage were occurring in a section. N3 and N4 show a very slight decline over time while S12 seems to have a slight increase over time. This may be due to the backcalculation process attributing some of the stabilized base material, which is curing over time, to the asphalt concrete. In any case, the backcalculated moduli values are signs of sound structures through this point of the experiment.

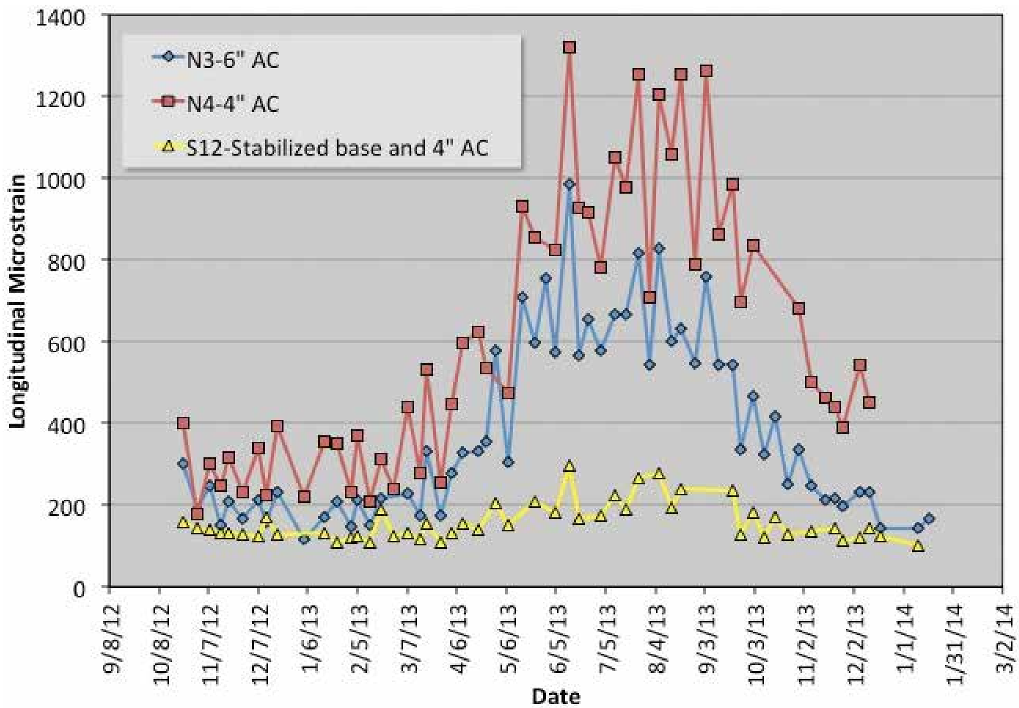

Figure 3 Strain response vs. time

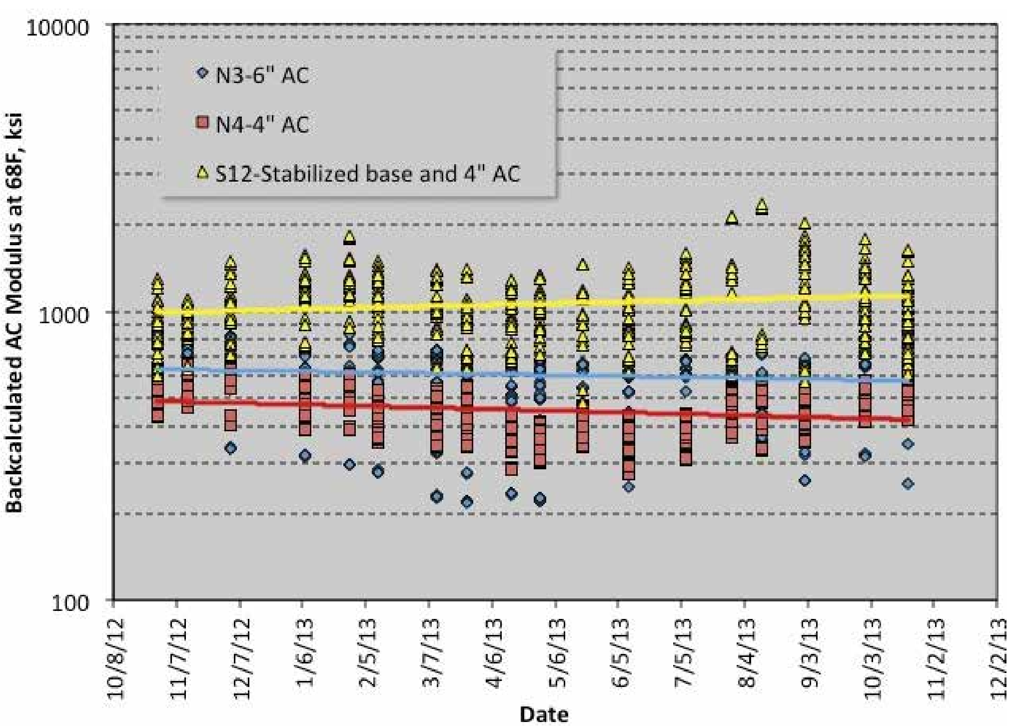

Figure 4 Backcalculated AC modulus at 68°F vs. time

Continuing Use of CCPR in Virginia

To date, both the I-81 recycling project and the CCPR test sections at NCAT are showing good performance. "VDOT is testing these recycling technologies in real-world heavy-application scenarios, and based on the successful performance we've seen so far, we'd like to move forward on additional projects," says Trenton Clark, Director of Engineering for the Virginia Asphalt Association. VDOT is currently revising their specifications for CCPR as well as developing permissive use specifications that will allow for alternate bids on cold recycling vs. traditional asphalt construction methods. A mix design class is also in the works to help contractors learn how to design cold recycled mixes and how to perform quality control testing during production.

How Accurate Are Designs Using the New Pavement ME Program?

Before the development of the Mechanistic-Empirical Pavement Design Guide (MEPDG) and recent release of AASHTOWare® Pavement ME software, most pavements in the United States were designed based on some version of the American Association of State Highway and Transportation Officials (AASHTO) design guide. AASHTO developed its first pavement design guide in 1961 as a result of its 1950s Road Test. This empirical-based design method had deficiencies including limited traffic loads, a single climatic area and a narrow range of materials used. These limitations, as well as advancements in material characterization, pavement performance evaluation and computing technology, led to the development of the MEPDG, and subsequently, Pavement ME (Mechanistic-Empirical) design.

Pavement ME design calculates pavement responses such as stresses, strains and deflections using a mechanistic approach. These responses are used as inputs in empirical distress prediction models to estimate cumulative pavement distresses over time. This predicted performance is adjusted on the basis of performance observed in the field, ideally bridging the gap between theory and the real world. The various distress prediction models for asphalt materials include total rutting, rutting in each layer (asphalt layer, base and subbase), top down cracking, bottom up fatigue cracking (longitudinal cracking), thermal cracking, reflective cracking and international roughness index (IRI). These projections allow engineers to define acceptable levels of performance and design pavements that address particular distresses.

The prediction models used in Pavement ME design, developed and nationally calibrated based on in-service pavements, were obtained primarily from the Long Term Pavement Performance (LTPP) program. These models may not account for local conditions such as the properties of materials and traffic loading. Consequently, any agency interested in using AASHTOWare® Pavement ME software must evaluate the nationally calibrated models to determine if they accurately predict field performance for local conditions. If not, the models must be calibrated. Otherwise, some pavements will be underdesigned and others overdesigned, translating to either premature failure or excessive costs.

Pavement ME design is a complex tool that demands technical skills and financial resources. The added time and expense of local calibration requires each agency to determine the extent of its investment as part of its implementation plan. As illustrated in Figure 1, local calibration is a systematic process expected to eliminate potential biases and increase the accuracy of the performance predictions. The potential benefits of Pavement ME design have been recognized by several states with varying levels of efforts toward implementation. Dr. Carolina Rodezno, a lead researcher at NCAT, is conducting an analysis of these efforts to determine whether local calibrations are effective in improving predictions of field performance.

At least ten states—Arizona, Colorado, Indiana, Missouri, Montana, North Carolina, Ohio, Oregon, Utah and Washington—have completed local calibrations of the asphalt concrete prediction models. The local calibration effort reported by each agency may only include calibration of some models and an evaluation of the applicability of global calibration factors. Also, the literature available sometimes lacks complete statistics in terms of R^2, standard error and bias. This makes the assessment of the calibration process difficult. The following was found from these calibration efforts:

- Nine states conducted a calibration of the rutting model. In general, it was found that the global calibration factors over-predict rutting. Calibration of the rutting model coefficients improved the accuracy of predictions when compared to the results before calibration (better R^2, reduction of standard error and/or reduction of bias). However, the overall accuracy ranged from fair to poor.
- Eight states conducted a calibration of the alligator cracking model. In some cases models with the global calibration factors over-predicted alligator cracking; in other cases the default models under-predicted fatigue cracking. Calibration of the model coefficients improved the predictions by improving the correlation in terms of R^2 and/or reducing the bias when compared to the results before calibration. Despite the improvements, the accuracy of the revised models still ranged from fair to poor.
- Only Oregon reported local calibration of longitudinal cracking.
- Colorado and Oregon conducted a calibration of the transverse cracking model, but unfortunately this didn't improve the prediction when compared

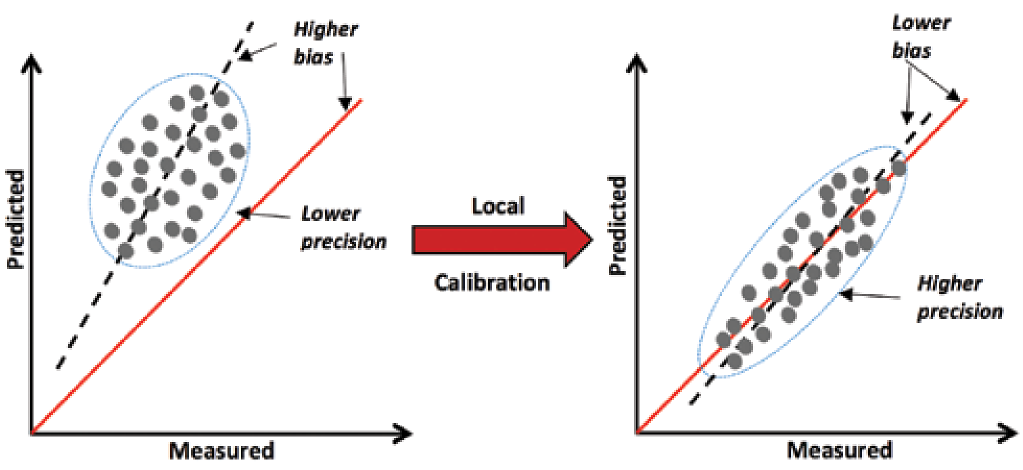

Figure 1 Precision and bias in local calibration

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PAVEMENT DESIGN GUIDE TIMELINE

1950s

1955
National Asphalt Pavement Association (NAPA) founded

1956
American Association of State Highway Officials (AASHO) begins Road Test experiment

1958
Inaugural Road Test traffic commences

1960s

1960
Road Test ends

1961
AASHO develops "Interim Guide for the Design of Flexible Pavement Structures"

1962
AASHO develops "Interim Guide for the Design of Rigid Pavement Structures"

1970s

1972
AASHO publishes "Interim Guide for Design of Pavement Structures"

1973
AASHO changes name to AASHTO, expanding to encompass all modes of transportation

1980s

1981
Revised design guide includes Chapter III: Guide for the Design of Rigid Pavement

1986
NAPA establishes National Center for Asphalt Technology (NCAT) at Auburn University

Significant revisions made to AASHTO "Guide for Design of Pavement Structures"

1987
Establishment of Long-Term Pavement Performance (LTPP) program

DNPS86/PC™ pavement design program available

1990s

1991
DARWin™ pavement design software is released

1993
Revised design guide includes overlay design procedure modifications

1996
National Cooperative Highway Research Program (NCHRP) Project 01-37 initiates development of new pavement design process

1998
Design guide supplement Part II: Rigid Pavement Design and Rigid Joint Design

NCHRP Project 1-37A begins to develop guide based on mechanistic-empirical (M-E) principles

2000s

2004
NCHRP Project 1-37A complete, resulting in "Mechanistic-Empirical Pavement Design Guide" (MEPDG) & release of MEPDG software

2008
AASHTO adopts MEPDG as interim pavement design standard

2010s

2011
DARWin-ME™ software is released

2013
AASHTOWare® Pavement ME Design software is released

with the nationally calibrated model.

- Only Colorado reported local calibration of reflective cracking. The prediction reported fair correlations with field performance.

It is important to mention that the AASHTOWare® Pavement ME software was conceived in a manner in which new capabilities and enhancements to the prediction models can be added as more research becomes available. Additional studies have been completed or are currently underway to improve the prediction models of this software, including:

1. NCHRP 9-30A: "Calibration of Rutting Models for HMA Structural and Mix Design" (completed)
2. NCHRP 01-41: "Models for Predicting Reflection Cracking of Hot-Mix Asphalt Overlays" (completed)
3. NCHRP 01-52: "A Mechanistic-Empirical Model for Top-Down Cracking of Asphalt Pavement Layers" (active)

Indiana, Missouri and Kansas have already implemented ME Design. The Indiana Department of Transportation began implementation in 2009 with the design of more than 100 pavement sections using the ME procedure. Their local calibration effort did not yield expected results, so they have continued with the default models and coefficients. However, comparisons were made with designs using the 1993 AASHTO Guide for Design of Pavement Structures. The MEPDG resulted in thinner pavement designs, typically in the range of 1.5 to 3 inches.

AASHTOWare® Pavement ME has the potential to improve pavement design, but a proper implementation can't happen overnight. Local calibration and validation prior to implementation must be an ongoing effort, and the performance models that have been developed nationally must continue to be improved. As designs are conducted with AASHTOWare software, they should be compared to the current design method as a quality control check until more experience is gained with the new approach, and until more accurate performance models are developed and adopted.

Reality Check: A critical look at MIT's fuel consumption research

Sustainable development, a dynamic process where both future and present needs are considered, has become a major subject of emphasis and debate in the pavement industry since the United Nations World Commission on Environment and Development defined the term 27 years ago. One focal point of recent sustainability efforts is motor vehicle fuel economy, as it directly impacts all three facets of the triple bottom line sustainability principle: social, environmental and economic. As fuel efficiency increases, fewer natural resources will be consumed, less greenhouse gasses will be produced and greater cost savings will be achieved.

In April 2012, the Concrete Sustainability Hub (CSH) at the Massachusetts Institute of Technology (MIT) released a report that investigated the effect of pavement type on vehicle fuel economy. This study, entitled Model Based Pavement-Vehicle Interaction Simulation for Life Cycle Assessment of Pavements, used a theoretical analysis to conclude that vehicles consume less fuel when traveling on stiff concrete roads than on asphalt pavements. However, a review of the report by Drs. Richard Willis and Mary Robbins at NCAT as well as Dr. Marshall Thompson, Professor Emeritus at the University of Illinois Urbana-Champaign, suggests that that the findings are flawed.

TRIPLE BOTTOM LINE OF SUSTAINABILITY

The term "sustainable development" has risen to importance after being introduced by the United Nations World Commission on Environment and Development (Brundtland Commission) in 1987. In the report *Our Common Future*, the term was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," informing the world that growth could be achieved without exhausting natural resources or harming the environment.

Sustainability can be seen as the capability to endure and preserve. Its three components, commonly referred to as the triple bottom line, incorporate economic prosperity, environmental responsibility, and social progress. It is only when these three concepts are aligned that something can truly be considered sustainable.

In February 2014, President Obama charged the Environmental Protection Agency and the Transportation Department to develop and issue new fuel economy standards for medium and heavy-duty vehicles by 2016. While this highlights the emphasis placed on improving the fuel efficiency of engines, there are many other factors that can influence the rate of fuel consumption. Pavement characteristics such as tire-pavement rolling resistance, pavement smoothness and pavement stiffness are frequent subjects of research to better understand their impacts on vehicle emissions and fuel efficiency.

In the CSH report, the researchers attempted to create a link between pavement deflection and fuel consumption. However, other studies have shown that pavement roughness and texture are the dominant factors that impact rolling resistance. The MIT study ignored these factors. Other variables—vehicle aerodynamics, speed, vehicle weight, engine type, tire traction, roadway grade and weather conditions—have important effects on fuel economy. A study that singles out one factor can be misleading.

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NCAT Researchers Explore Multiple Uses of Rejuvenators

A limited number of agencies have used rejuvenators as a method of slowing down the effects of aging of asphalt pavement surfaces. Used as a pavement preservation technique since the 1960s, rejuvenators are intended to help restore certain physical and chemical properties of aged asphalt binders. Because they contain a high proportion of maltene constituents, the aim of rejuvenators is to help restore the balance between maltenes and asphaltenes that changes during the aging process. There are various types of pavement rejuvenators, as shown in Table 1.

The structure of asphalt is a complex colloid in which insoluble asphaltenes are the dispersed phase and soluble maltenes (also known as petrolenes) are the dispersion medium. Maltenes are further subdivided into resins (or polar aromatics), naphthene

CATEGORY	EXAMPLES	DESCRIPTION
Paraffinic Oils	Waste Engine Oil (WEO) Waste Engine Oil Bottoms (WEOB) Valero VP 165® Storbit®	Refined used lubricating oils
Aromatic Extracts	Hydrolene® Reclamite® Cyclogen L® ValAro 130A®	Refined crude oil products with polar aromatic oil components
Napthenic Oils	SonneWarmix RJ™ Ergon HyPrene®	Engineered hydrocarbons for asphalt modification
Triglycerides & Fatty Acids	Waste Vegetable Oil Waste Vegetable Grease Brown Grease Oleic Acid	Derived from vegetable oils
Tall Oils	Sylvaroad™ RP1000 Hydrogreen®	Paper industry byproducts Same chemical family as liquid antistrip agents and emulsifiers

Table 1 Types of pavement rejuvenators

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aromatics (also known as cyclics or aromatics) and saturates (known as paraffins or paraffinic oils). In the presence of sufficient quantities of maltene components, the asphaltene micelles are fully dispersed and have significant mobility within the asphalt.

Physical changes in an asphalt binder over time are dependent on changes in its chemical composition. Oxidation, or weathering, eventually occurs in all asphalt pavements. The rate of weathering depends on several factors, including the chemical characteristics of the original asphalt binder, environmental conditions, and how much the binder in the mixture is exposed to air and ultraviolet radiation. As asphalt ages, the aromatics are converted to resins and the resins are transformed to asphaltenes due to the addition of oxygen. During this process, the ratio of maltenes to asphaltenes is reduced, leaving fewer maltenes available to disperse the asphaltenes. This results in higher viscosity and lower ductility, which influences the ability of asphalt binder to stretch without breaking. In other words, when the asphaltene micelles are not sufficiently able to flow past one another under the applied stress, the result is a dry and brittle pavement.

From a rheological perspective, the asphalt hardening observed with oxidation is accompanied by a substantial loss in binder phase angle, which is a critical element of "asphalt healing" following minor damage. Asphalts do not experience this same loss in phase angle when distilled to equivalent harder grades in the refinery. The key to effective binder recycling is not only to soften the aged asphalt back to the consistency of the virgin binder, but also to restore the original phase angle. Softening the aged binder with any softer oil or asphalt is quite easy, but restoring the original binder phase angle represents a difficult challenge to any formulator of recycled mixes. This challenge becomes increasingly difficult as the carbonyl content of the recycling blend increases, either through higher RAP content or by using highly oxidized asphalts such as found in recycled asphalt shingles.

Asphalt rejuvenators can be surface applied to existing asphalt pavements, although they must be able to penetrate the surface in order to improve or restore the balance of maltenes to asphaltenes. When properly applied, rejuvenators soften and lower the viscosity of the binder, improve flexibility and reduce the brittleness of the pavement and probability of cohesive failure. Rejuvenators can also help seal the pavement against the intrusion of air and water, thus slowing oxidation, reducing raveling and moisture damage, and protecting the pavement, ultimately increasing durability and extending the pavement's life cycle.

Rejuvenators have the potential to extend the life of an asphalt pavement for several years beyond the point when rehabilitation or major reconstruction would normally be required, significantly decreasing annual maintenance costs. While rejuvenators have been used previously with hot in-place recycling, cold in-place recycling, and spray applied fog seals, new products are currently being evaluated to determine how well rejuvenators may improve the cracking resistance of mixes containing a high percentage of recycled material.

Although the use of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) in asphalt mixtures is steadily increasing, many transportation agencies are reluctant to allow over 30 percent recycled binder content in asphalt mixtures due to potential construction and performance issues. The main concern with the use of relatively high percentages of recycled binders is that they are stiffer and less ductile than virgin binders. Consequently, mixtures with RAS or high percentages of RAP can be more susceptible to pavement distresses such as fatigue, thermal and reflection cracking.

Although rejuvenators have been used in pavement preservation and cold in-place recycling, they have not been widely used in hot-mix asphalt (HMA) and warm-mix asphalt (WMA) mixtures containing high recycled binder contents because of uncertainty regarding the degree of blending between the rejuvenator and the recycled binder or how high mix temperatures affect rejuvenators. Research has also been stifled in the past by a lack of methods to confidently assess different modes of cracking in asphalt mixtures. Therefore, NCAT and other researchers are exploring how different rejuvenators can be used to enhance the cracking resistance of HMA and WMA mixtures with high recycled binder contents.

The economic and environmental benefits of using reclaimed materials necessitate research to better understand the potential of using rejuvenators in HMA and WMA mixtures with high recycled binder contents. Through laboratory and field experiments, NCAT is currently evaluating how rejuvenators can revitalize oxidized RAP and RAS binders and plans to ultimately demonstrate that pavements can use high recycled binder contents and achieve better long-term performance.

Does WMA Help Improve Density?

One of the reasons most contractors utilize warm mix asphalt (WMA) technologies is to help improve the compactability of mixes during construction. Since most highway agencies apply a penalty and/or bonus for in-place density, there is a financial motivation for achieving a higher level of density for every layer. However, in National Cooperative Highway Research Program project 9-47A, NCAT's analysis found the in-place densities for WMA and HMA were not statistically different on most of the field projects examined during the study.

NCAT Assistant Research Engineer Grant Julian, who was on each project, explains that seven cores were obtained following construction for each WMA and companion HMA sections. "Contractors used the same roller patterns on the WMA and HMA sections. The only real difference between the WMA and HMA section was the WMA technology and lower temperatures. On average, the WMA mixes were produced 42 degrees Fahrenheit lower than their companion HMA mixes."

Figure 1 shows the comparisons of the in-place densities for the WMA and HMA sections on a project-by-project basis. A *t*-test was conducted on the data for each project. Only the project from Casa Grande, AZ, using an organic WMA additive, had a statistically significant higher density for the WMA compared to HMA.

"At first, we were surprised with the results of the density comparisons," says Dr. Carolina Rodezno, NCAT Assistant Research Professor and lead researcher for WMA projects. "However, we realized the important difference between something being *statistically significant* and *practically significant.*"

From the NCHRP 9-47A data, the average density improvement for WMA compared to HMA was only 0.17% of G_{mm}. Since in-place density data typically has a standard deviation of about 1.5%, that small density improvement is not significant from a statistical point of view. However, there can be a practical significance even for a small density improvement.

To illustrate this point, NCAT engineers examined the effect that a 0.17% higher density would have on payment for projects using a percent within limits (PWL) incentive/disincentive specification. Actual in-place density data from six randomly selected projects in Florida were used in the example. The Florida DOT PWL specification allows each lot of mix to receive up to a 5% bonus or a penalty as low as 80% of the bid price depending on the PWL analysis. Density is one of four parameters used by FDOT in the calculation of the composite pay factor for each lot. Density has weighting factor of 0.35, the highest of the four pay items used in the calculation of the composite pay factor. A typical bid price of $85/ton for Florida mixes was used in this analysis. A summary of the project information and the results of the hypothetical analysis are shown in Table 1. To simplify the analysis, partial lots were excluded.

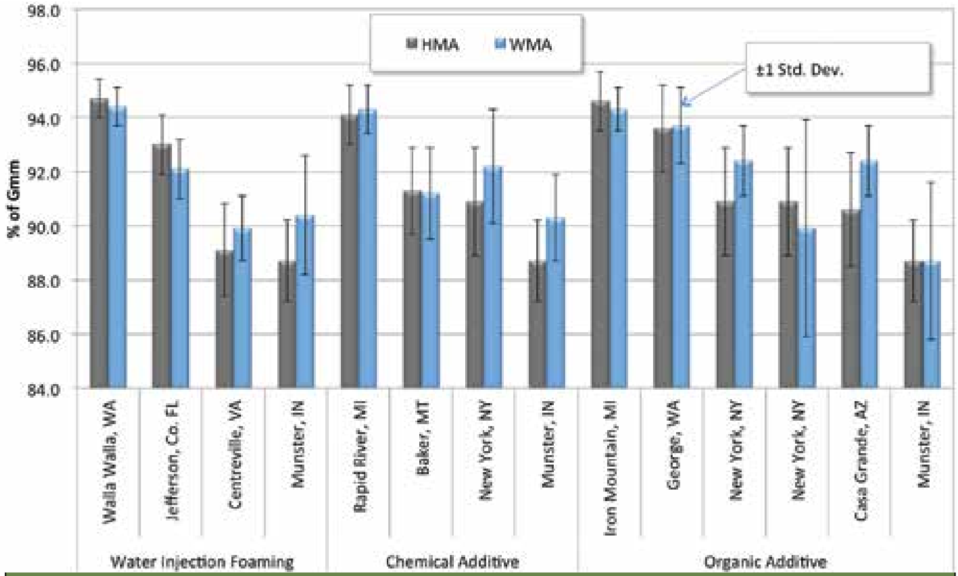

Figure 1 Comparison of WMA and HMA in-place density results after construction

Project 3 had already achieved the highest possible pay factor for density on all lots, so there was no opportunity for a financial benefit for a higher density by using WMA on that project. Project 4 also had a high average pay factor for density, so a

Project	Project Tons*	Actual Average Density Pay Factor	Adjusted Average Density Pay Factor	Hypothetical Savings $/Ton	Hypothetical Dollar Benefit for the Project
1	64,000	0.94	0.97	$1.13	$72,320
2	108,000	0.94	0.96	$0.51	$55,080
3	48,000	1.05	1.05	$0	$0
4	92,000	1.03	1.03	$0.09	$8,280
5	75,000	1.01	1.02	$0.25	$18,750
6	92,000	0.87	0.91	$1.10	$101,200

*partial lots were not evaluated

Table 1 Hypothetical impacts of WMA on density pay factors and mix savings

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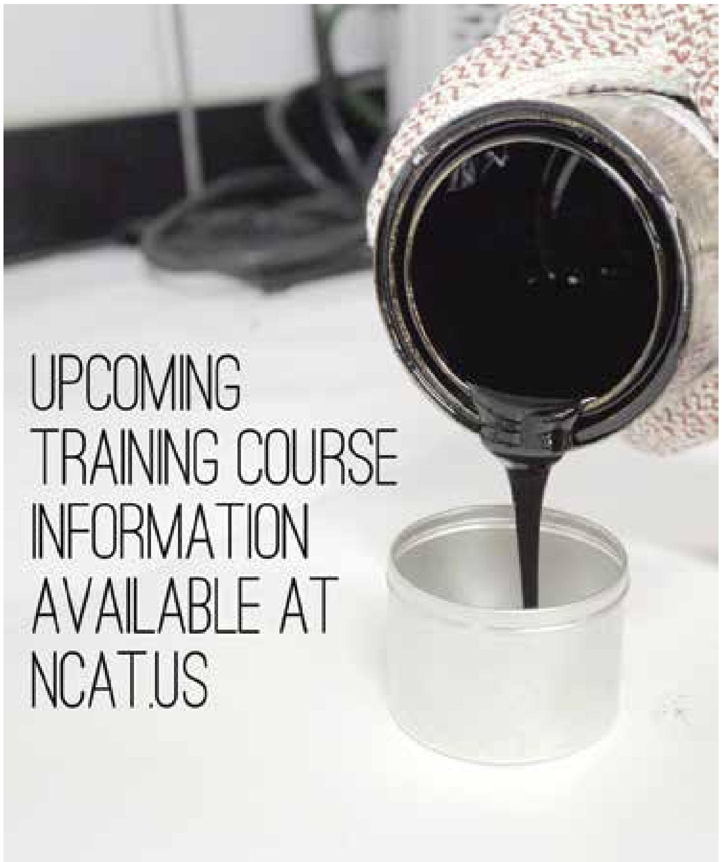
higher density for WMA was an advantage for only a few lots. The greatest advantage of the hypothetical 0.17% increase in density for WMA would occur on projects that often had pay deductions for density. Because a small improvement in density can have a substantial impact on the overall payment that contractors receive on some projects, many use WMA for this benefit alone.



Reality Check: A critical look at MIT's fuel consumption research

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Of all pavement characteristics, smoothness and texture have consistently been found to be the major pavement determinants of vehicle fuel efficiency. Past research on pavement rolling resistance, or the amount of energy required to keep a wheel in motion, has shown that more energy is required to propel a vehicle over a rough surface than over a smooth surface. Not only do smoother pavements lower fuel consumption, but they also have been shown to last longer, lessen driver fatigue and lower vehicle operating costs, incorporating each aspect of the triple bottom line sustainability principle.

The CSH research claimed that all pavements modeled were designed to carry highway traffic. However, that was not the case. The concrete sites were generally designed for higher traffic, or a longer life, than the asphalt sites. The modeled pavements were also not a representative sampling of the national highway network, so extrapolation of the results to the entire system is not appropriate.

Although the CSH research claims the study was not about asphalt versus concrete, similar conclusions have only been drawn in concrete industry research and have not been proven in studies by independent researchers. Several details of the CSH work are not adequately documented. Dr. Willis' team's examination of the CSH data and modeling approach continues. A full report of their review will be released in the near future.

The ultimate goal of sustainability is to ensure that our actions today have a positive impact in the future. The industry is eager to become more sustainable and has made some great strides to meet the triple bottom line. However, there are more opportunities ahead. Let's push the envelope to make the industry better and not be sidetracked by unsound research.

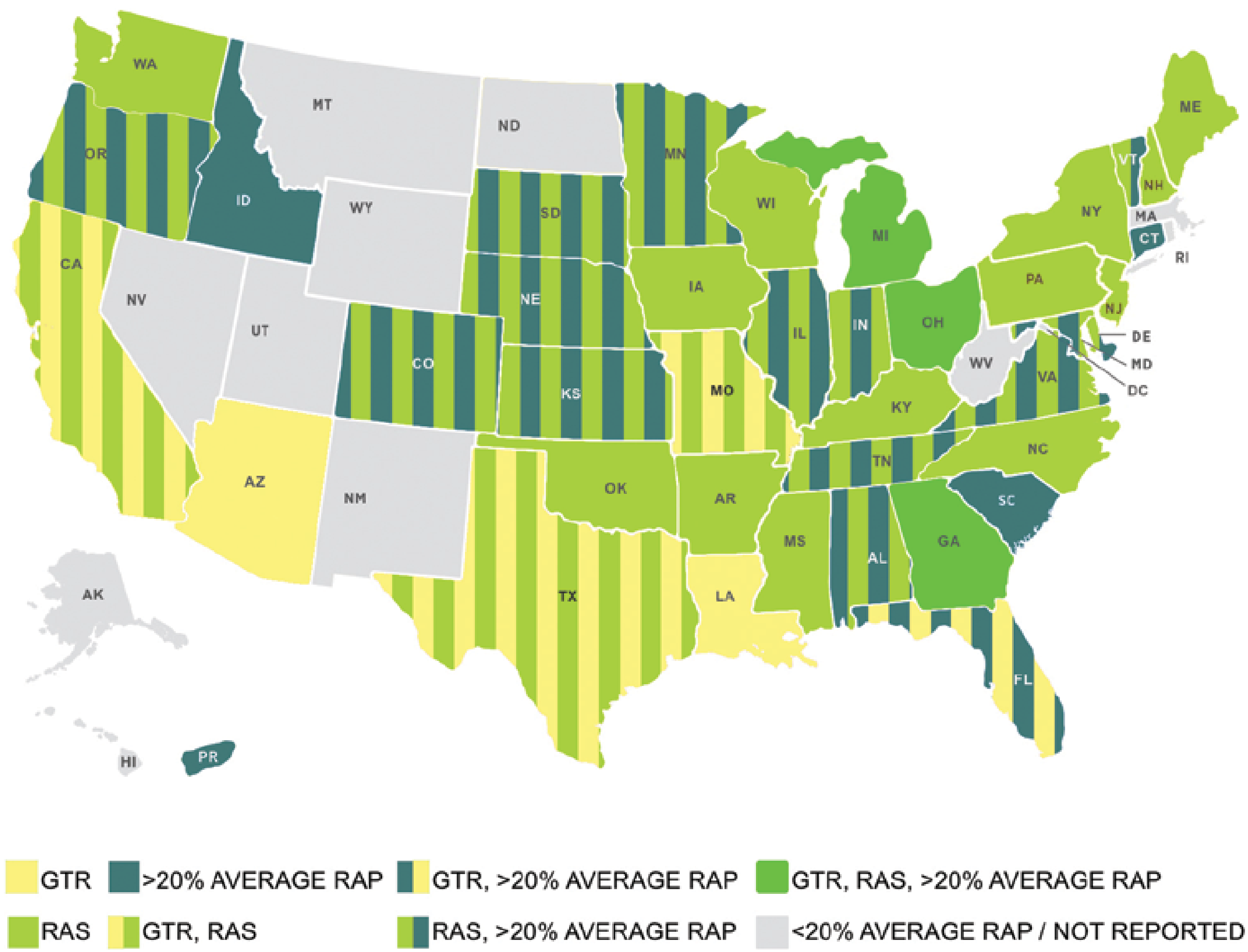
Recycled Materials Provide More than Economic Benefits

The use of recycled materials in asphalt mixtures is continuing to rise, according to the results of a survey recently released by the National Asphalt Pavement Association (NAPA). Economic savings and a focus on sustainability are generally credited as primary motives for the increasing use of reclaimed asphalt pavement (RAP), recycled asphalt shingles (RAS) and ground tire rubber (GTR) by the asphalt pavement industry.

For the first time since the beginning of this annual survey in 2009, the amount of RAP and RAS used by producers has exceeded the amount collected. RAS usage has increased to 1.86 million tons in 2012, an almost 95 percent increase. RAS is used in 37 states, including both post consumer tear-off shingles and manufacturer waste. More than one million tons of other recycled materials including GTR were also reported by NAPA as being used in asphalt paving mixtures.

GTR serves as an asphalt modifier, which can ease the industry's dependence on the supply of polymers. When RAP and RAS materials are reused and the recycled binder is reactivated,

2012 REPORTED USE OF RECLAIMED ASPHALT PAVEMENT (RAP), RECYCLED ASPHALT SHINGLES (RAS) AND GROUND TIRE RUBBER (GTR) IN PAVEMENTS



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the demand for virgin binder is reduced. The demand for new aggregate is also reduced. The use of RAP and RAS in 2012 saved an estimated $2.2 billion in asphalt binder costs alone.

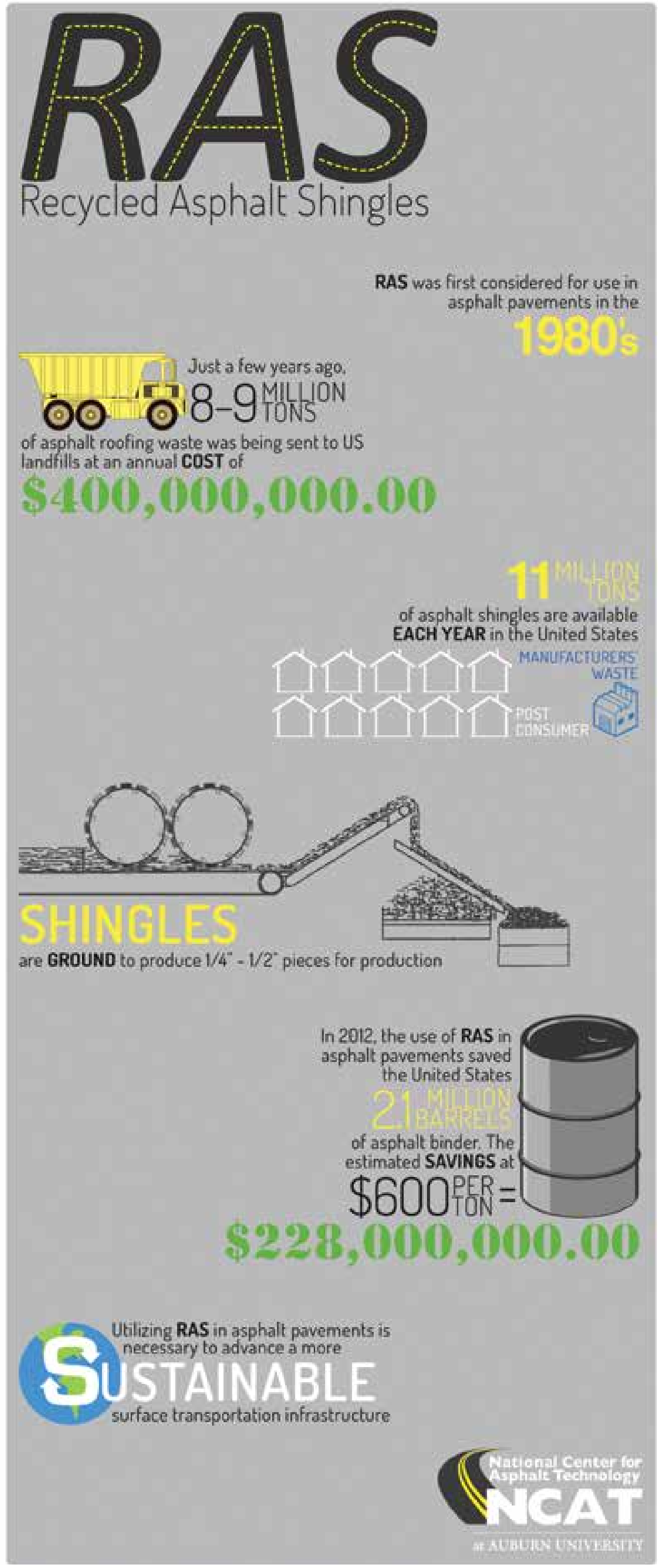
Studies are currently underway by several research organizations to examine different methods of incorporating GTR in various climates. Two different processes currently being utilized are asphalt-rubber and terminal blend. Asphalt-rubber has been successfully used for over 35 years in Arizona, and California. There are two types of asphalt-rubber binder, Type I and Type II. Arizona and Texas use Type I, which contains 18 to 20 percent GTR by binder weight. California uses Type II, which consists of about 20% GTR by binder weight. Both Type I and Type II have been shown to combat bottom-up fatigue cracking. Terminal blend binders have been used with 7 to 12 percent GTR in Florida to provide a flexible mix that performs as well as, or in most cases, better than polymer-modified asphalt in terms of resisting rutting and top-down, or surface cracking.

During the past few years, most states have increased the maximum allowable RAP content in asphalt mixtures and allow up to 5 percent RAS, resulting in an overall increase in the allowable recycled binder content of mixtures. Some Departments of Transportation, such as Chicago and New York City, are producing mixes containing 30 to 50 percent recycled asphalt binder, as confidence grows that these mixes can have acceptable performance when good mix design and construction practices are followed.

While some fear that the use of recycled materials may produce substandard asphalt mixtures, state agencies such as Texas, Florida, Wisconsin and Illinois, have spent time and resources understanding material characterization, mix design and mixture production in order to build high-performance roads at a cost-effective price. Recycled materials such as RAP and RAS inherently increase the stiffness of an asphalt mixture. This increase can be used in mechanistic pavement design scenarios to either reduce the overall tensile strain at the bottom of the asphalt or reduce the necessary thickness to attain equivalent strain magnitudes. It also allows DOTs to use unmodified asphalts in wearing course mixtures where polymers might otherwise be required to prevent rutting.

Studies have shown that using either GTR or RAS in specialty mixtures such as open-graded friction courses and stone-matrix asphalt (SMA) can allow contractors to prevent drain-down without the use of additional fibers. Drain-down, which occurs when the asphalt binder migrates to the bottom of a mix between production and compaction, can lower the long-term durability layer. In addition to removing additional fibers from the mixtures, using these recycled materials to modify the mix can also eliminate the need for using a polymer-modified binder to avoid rutting.

It is recommended that agencies considering using or increasing the use of recycled materials look to other agencies that have strong recycling programs for guidance. It is also essential that contractors and agencies understand how RAP, RAS and GTR can change the properties of an asphalt mixture and tailor those differences to their advantage.



Asphalt Forum

NCAT invites your comments and questions, which may be submitted to Christine Riggs at cjriggs@auburn.edu. Questions and responses are published in each issue of Asphalt Technology News with editing for consistency and space limitations.

Jerry Geib, Minnesota DOT
Minnesota DOT has purchased a DCT (disk-shaped compact tension) testing machine to measure fracture energy. Early test results confirm that higher fracture energy mixes are more resistant to thermal cracking.

Oak Metcalfe, Montana DOT
We appear to be having an issue in Montana with our CRS-2P emulsions "reactivating" at higher mat temperatures. The material doesn't fail our distillation and penetration tests, but if the ambient temperature rises after application the emulsion allows for chips to roll and causes all sorts of splash. Ultimately, the emulsion cures and the chip seal performs. Do you believe this is a crude source issue? We allow the use of latex for modification, which could also be a problem.

Eric Biehl, Ohio DOT
We are concerned with the use of RAS in Ohio, especially in surface mixes and the lack of free asphalt available. What courses do you allow RAS? What is the maximum amount of RAS allowed? Do you have a correction factor for RAS binder in mix designs? Any data available on durability with mixes with RAS in them? Any other special requirements such as mixing temperatures, use of WMA, etc.?

Cliff Selkinghaus, South Carolina DOT
Have any states had experience using 9.5mm in lieu of 12.5mm OGFC on an interstate or other high ADT routes? Do you feel like there is a need to use PMA and fibers in those finer OGFC mixes, especially since we have WMA and other means to reduce draindown?

Chris Jones, Wiregrass Construction Company
What states use RAP and RAS together? If so, in what maximum percentages? If not, do you have any plans for trial projects to determine feasibility as a cost-saving measure?

Asphalt Forum Responses

The following responses have been received to questions shared in the Fall 2013 Asphalt Forum.

1. For mix designs, the specific gravity of fine aggregate is verified by our district labs. Does your state or agency:
    1. Assign a statewide value to each aggregate source for +4 or -4 material
    2. Require the contractor to report the specific gravity of each individual component and verify
    3. Other:

    (Chris Abadie, Louisiana DOTD)

Michael Stanford, Colorado DOT
Colorado requires the contractor to report the specific gravity of each individual component and verify.

Greg Sholar, Florida DOT
Florida assigns a statewide value to each aggregate source for +4 or -4 material.

Jerry Geib, Minnesota DOT
Minnesota requires the contractor to report the specific gravity of each individual component and verify.

Oak Metcalfe, Montana DOT
Montana requires the contractor to report the specific gravity of each individual component and verify.

Denis M. Boisvert, New Hampshire DOT
New Hampshire requires the contractor to report the specific gravity of each individual component and verify.

Eric Biehl, Ohio DOT
Ohio assigns a statewide value for each aggregate size (i.e. coarse aggregate materials such as 4, 57, 8, 9, 7 etc. and fine aggregate materials such as sand and screenings), not just one value for +4 and -4.

Cliff Selkinghaus, South Carolina DOT
We use our yearly QPL for each aggregate source in South Carolina.

Mark E Woods, Tennessee DOT
Our contractors report specific gravity with designs but the state does not verify.

Howard Anderson, Utah DOT
Utah requires the contractor to report the specific gravity of each individual component and verify.

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2. States with abundant supplies of high quality, polish-resistant aggregate have little trouble managing asphalt pavement surface friction. States with few or no in-state friction aggregate sources must place more emphasis on the quality and quantity of friction aggregate in their asphalt mixture design specifications. If you are a friction aggregate-poor state, how do you specify the quantity of friction aggregate in asphalt surface mixtures?
(Michael Heitzman, NCAT)

Michael Stanford, Colorado DOT
Colorado tends to have high quality, polish-resistant aggregates.

Greg Sholar, Florida DOT
Florida has a few limestone mines approved for friction courses. For our Florida limestone aggregates there must be 12% silica in the stone to be used as a friction aggregate. These aggregates must be used at 100% of the mix design with no RAP or any other non-approved limestone. Non-approved friction limestone and up to 20% RAP can be used If a contractor uses at least 60% granite in those designs. These values were determined based on test sections constructed years ago at several locations in Florida.

Jerry Geib, Minnesota DOT
Minnesota has good aggregates.

Eric Biehl, Ohio DOT
For the aggregate portion, see the guidelines from the link below. For the mixes, Ohio DOT, through a research project with the University of Akron, developed a test to simulate the polishing of a pavement over its lifetime in eight hours.

http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Aggregate1/SR_Pavement_Friction_Guidelines.pdf

Cliff Selkinghaus, South Carolina DOT
We have very good aggregates for the most part in South Carolina; however, we have started using high friction surface treatments often with on-off ramps on our interstates to improve friction resistance based on data from our Traffic-Safety Office.

Mark E Woods, Tennessee DOT
In Tennessee's limestone region, limestone sources are categorized as Type I, Type II, etc. depending on their ability to resist polishing. Type I is the most polish resistant. Type IV is polish resistant enough, and only permitted on lower-traffic roadways (<5000 ADT). All surface mixtures must contain a minimum of 75% non-polishing aggregate, appropriate to the correlated traffic levels.

Howard Anderson, Utah DOT
We have good hard aggregates for most of the state of Utah. Because we have some softer limestone pits we use LA Abrasion 35% min, Sodium Sulfate Soundness 16% max loss from 5 cycles. For chip seals and micro-surfacing we add the Polish Value tests (British Pendulum) for our aggregates of 31 min and change the LA Abrasion to 30 and the Sodium Soundness to 15.

3. Do any states have specifications requiring paver tunnel extensions? What advantages/disadvantages have you observed from having/not having this spec?
(Mark Woods, Tennessee DOT)

Michael Stanford, Colorado DOT
Colorado has no experience with this.

Greg Sholar, Florida DOT
Florida does not have a requirement.

Jerry Geib, Minnesota DOT
Minnesota has no requirement for paver tunnel extensions.

Eric Biehl, Ohio DOT
Ohio does specify the use of full tunnel extensions (Item 401.15). However, I'm not sure if there have been any pros or cons to this. We also require full auger extensions, although these are sometimes not enforced.

Cliff Selkinghaus, South Carolina DOT
No specifications yet for tunnels in South Carolina, but likely a good idea to help prevent segregation along with doing the same for adding auger extensions.

Howard Anderson, Utah DOT
Utah has no requirement for this yet.

Florida

FDOT will be requiring the exclusive use of trackless tack starting January 2015.

FDOT's end-of-load segregation specification based on obtaining density cores in segregated areas has been working well to correct the problem. The material must be removed and replaced if the average of three cores is less than 90% Gmm.

Minnesota

MnDOT will use an infrared bar on 20 projects. We will use IC on 9 HMA jobs for roller coverage (we will collect the IC data but will not be using the stiffness for density).

Montana

Montana is considering eliminating our long time requirement of the Volume Swell test on HMA aggregates for acceptance. The Volume Swell is a Montana-specific test developed several years ago in-house, based on some of the older bituminous fine aggregate swell tests. Montana has allowed it as an alternative method for aggregate acceptance to the standard Sand Equivalent test.

New Hampshire

Following the agreements made at the 2013 NEAUPG (Northeast Asphalt User-Producer Group) Annual Conference (Oct. 2013), NHDOT will be specifying and testing its polymer-modified binders using AASHTO MP 19 MSCR grading in 2014. A binder failure penalty has been added. A 10% reduction will be assessed for one grade below the specified high grade and/or one grade above the specified low grade. Two grades off specification may result in removal or 50% payment.

Ohio

Ohio DOT recently added the option of using hot applied asphalt joint adhesive to longitudinal joints.

Ohio DOT recently developed a specification for the use of a moisture analyzer to determine the asphalt residue percent in asphalt emulsions.

Ohio DOT is doing in-house research using the asphalt binder cracking device (ABCD; AASTHO TP-92) with virgin, RAP, and RAS binders at different percentages and combinations to look at the effects of low-temperature cracking.

South Carolina

SCDOT hopes to have a new binder specification out this spring, which includes the option of GTR modification as well as small doses of PPA PG 76-22.

SCDOT will allow -30 mesh GTR (ambient or cryogenic) to be added at a minimum of 7%.

SCDOT is implementing MSCR (V-grade) in addition to M320 for PMA binders.

Tennessee

Tennessee now permits the use of post-consumer recycled shingles (RAS) in asphalt mixtures. All RAS must be 100% passing the 3/8" screen and 90% passing the #4 screen. Base and binder mixtures must contain a minimum 65% virgin asphalt and surface mixtures must contain 80% virgin asphalt. RAS suppliers are subjected to a certification process.

Utah

We have a couple of special provisions out to work on getting more asphalt binder into our mixes and increasing the density and quality of our longitudinal joints. This is due to our mixes becoming too dry with durability being an issue. Our long joints also need to improve.

NCAT Asphalt Technology Course
February 24-28, 2014

Front Row (L-R): Grant Julian (Instructor), Ed Bush, Don Watson (Instructor), Michael Heitzman (Instructor), Mike Vondra
Middle Row (L-R): Pamela Turner (Instructor), Darren Moritz, Michael Terry, James Landry, Kurt Muehlemeyer, Joel Dagnillo, John Harris, John Hardy, Greg Potts, Scott Wenger, Noe Hernandez, Dallas Pyzik, Gary Carroll, Randy Peterson, Brian Ware, Erik van der Heijden
Back Row (L-R): Jason Moore (Instructor), Ian Arp, Troy Kutz, Jim Katzer, Jason Walker, Hans Jorgensen, Adam Taylor (Instructor)

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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 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.