Fall 2022
Vol. 34, No. 2

Asphalt Technology News

Features

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Contents

Message from the Director

It's a well-understood principle of civil engineering that long-lasting structures begin with a firm foundation. This applies not only to buildings, dams, and bridges, but also to pavements. Unfortunately, on many occasions, I've seen first-hand where a well-designed and produced asphalt mixture and well-constructed overlay were built on top of an existing pavement structure with a serious problem. The outcome of this scenario is predictable, and the cost is not just in dollars and cents, but also a damaged reputation for the agency and the contractor, and another data point indicating that asphalt pavements aren't durable.

With that in mind, it concerns me to hear about "standard" pavement rehabilitation strategies, such as a 2.5-inch mill and fill, where there is essentially no engineering in the decision about what's needed to correct the underlying distress. I know it's not just me; I've heard similar complaints from pavement stakeholders across the country.

I was once involved in a case where an expensive interstate rehabilitation project failed because the underlying patches and leveling that had been covered in the previous rehabilitation were stripping and crumbling. I've also seen numerous overlays fail prematurely because they were paved over a milled surface that was riddled with scabs left behind from the milling operation. Recently, I examined a set of over 60 cores for a project on a US highway scheduled for rehabilitation because it had extensive longitudinal and fatigue cracking ranging from 18 to 33% of the lane area. 75% of the cores had debonded between the last overlay and the underlying asphalt pavement.

This lack of pre-design investigation is especially frustrating because we have many tools available to evaluate the structural health of a pavement. Although pavement condition surveys can provide information about the type, magnitude, and extent of distresses, they don't tell us the cause. Falling weight deflectometer (FWD) tests and ground penetrating radar (GPR) can provide additional information about the structural health of a pavement, but the interpretation of data from those tools is imperfect. In my mind, nothing can substitute for good, old-fashioned coring to evaluate the condition of the underlying pavement. Coring can tell us so much about an existing asphalt pavement. It can tell us the actual thickness of asphalt layers, the condition of those layers, the types of mixes used, the depths of any cracking, and also if there is any stripping or delamination between layers.

I've heard the argument that agencies don't have enough funding to do a proper rehabilitation to fix underlying problems. I understand budget constraints, but an agency that repeatedly fails to consider the long-term costs of covering up underlying issues is wasting taxpayer money. Taking the time and effort to understand what exists below the surface is the first step to achieving better performing rehabilitated pavements.

Randy C. West, Ph.D., P.E.
NCAT Director and Research Professor

MnROAD Additive Group Test Section Construction

Full-scale accelerated pavement testing has been conducted at the Minnesota DOT Road Research Facility (MnROAD) and the NCAT Test Track for more than two decades. These proven and practical research facilities formed a partnership in 2015 that is cooperatively funded by state DOTs from all over the country to execute flexible pavement studies targeting national research priorities.

The objective of the additive group (AG) experiment, sponsored by seven state DOTs and FHWA, is to measure the impact of recycled and premium mix additives on pavement life in both southern and northern US climates. Southern sections were built on the NCAT Test Track in the summer of 2021 to quantify the impact of the mix additives on fatigue cracking. Northern sections were built on the MnROAD high-volume I-94 interstate mainline bypass in the summer of 2022 to quantify the impact of the mix additives on thermal and reflective cracking.

For the MnROAD test sections, mix designs with the additives were developed using a balanced mix design (BMD) approach at NCAT in the spring of 2021. Aggregates and binder grades appropriate for southcentral Minnesota were utilized. Five inches of a control mix was placed in two 2.5-inch lifts on carefully prepared base, subbase, and subgrade materials common for Minnesota in each of the 450-foot AG test sections. Full depth (24-inch) transverse saw cuts were made at 25- and 50-foot spacings to simulate existing thermal cracks. The top inch was milled off, CSS-1H tack was applied at a bar rate of 0.07 gallons per square yard, and all research mixes were placed in a 2-inch lift on the surface. Milling was completed by Caterpillar, the mix was produced by Martin Marietta at their Elk River, MN plant, and the mix was placed by C.S. McCrossan from Maple Grove, MN. All mix was produced and placed the week of July 18, 2022. NCAT was responsible for plant settings and mix quality testing at the Elk River asphalt plant. The NCAT portable laboratory was set up at MnDOT's Elk River truck yard just a few miles down the road from the asphalt plant.

Dry recycled tire rubber and recycled plastic additives were introduced into the Dillman counterflow drum plant with a Hi-Tech Asphalt Solutions feed system. Both brands of high strength aramid fibers were introduced into the plant using portable systems provided by the manufacturers. Rates were independently verified and documented by NCAT personnel. Wet additives were pumped directly from preblended tanker trailers that were temporarily plumbed to the plant. Practice mix (typically 100 tons) was sampled at the plant, transported to the truck yard, and tested in the NCAT portable lab. Asphalt content, washed gradation, and volumetric properties were measured to make sure the produced mix was proportioned in accordance with the mix design. Additionally, both IDEAL-CT and Hot-IDT samples were prepared. Plant settings were adjusted as necessary by NCAT, and mix was produced (typically 200 tons for each section) and hauled to the jobsite for placement.

High volume I-94 Interstate bypass mainline test sections at MnROAD.

NCAT staff also collected data at the plant and construction site to support the life cycle assessment (LCA) of the additive. Particulate matter sensors provided by Applied Particle Technology, Inc. were installed at the top of the mix storage silo on each side of the batcher. Sensor data was transmitted via wireless connection to cloud storage for further analysis. Feedstock material quantities, burner fuel consumption, and electricity measurements required for cradle-to-gate LCA stage were documented for each mix. Operational and idling times of construction equipment (material transfer vehicle, paver, and compactors) were documented to quantify each test section's construction phase emissions. The performance data collection required for quantifying use stage LCA will continue when the mainline is open to traffic.

MnROAD personnel were responsible for monitoring paving operations and collecting mat quality data such as density and smoothness. Intelligent construction technologies were utilized extensively in this effort. A paver mounted thermal imaging system documented thermal uniformity, and ground penetration radar (GPR) was used to verify thickness consistency. Intelligent compaction was used to document the compaction process, nuclear gauges corrected to cores were used to establish rolling patterns and measure spot densities, and a density profile system measured density over the entire section. Construction quality was very good with preliminary densities for all the additive test sections ranging from a low of 94.5% to a high of 95.9% with an overall average of 95%.

NCAT's portable laboratory at the MnDOT Elk River truck yard.

The northern AG sections are opening to traffic in fall 2022 after all construction activities and baseline data collection have been completed. The observed performance of each section will be compared to a conventional control section with a focus on thermal and reflective cracking. Any additive section that statistically outlasts the control section will be a demonstration of improved performance.

Truck lane paving at the southeast end of MnROAD's I-94 Interstate bypass mainline.

Contact Buzz Powell (left) at buzz@auburn.edu, Nathan Moore (center) at nathan.moore@auburn.edu, or Suri Gatiganti (right) at szg0094@auburn.edu for more information about this project.

The Road to Zero: Can we achieve zero emissions? *And why we should.*

For years, when you heard the word "climate," you may have thought about a "climate controlled" lab or the "business climate" your organization is operating in. While this still may be the case, the word climate has taken on a new and important meaning in the infrastructure world over the last decade. Many now associate climate with weather, and that would be correct, albeit it's the weather (precipitation, wind, etc.) over many years.

Evidence is clear that we're affecting our climate through greenhouse gas emissions such as carbon dioxide, methane, and others. The Intergovernmental Panel on Climate Change (IPCC), the United Nations body responsible for assessing the science of climate change, released the Sixth Assessment Report in 2021. This report highlighted the impact that humans are having through greenhouse gas emissions on changing the temperature of the earth and shifting climate patterns. This is leading to more extreme temperatures and storms that affect our infrastructure and livelihoods.

Many paint a "doom and gloom" portrait of climate change, and there is some merit to that, but I view it as opportunity: opportunity to learn what's working and not working, and an opportunity for a creative design challenge. We are in a tough spot, so what are we going to do about it?

WHY SHOULD WE CARE?

We can't ignore climate change, so let's consider reasons we should care. For one, it's the right thing to do. Lower greenhouse gas emissions and reduced energy use, among other indicators, leads to a healthier earth and a more equitable society, both of which are integral parts of our day-to-day lives. Like clean water and air? Me too. Like taking care of your neighbors? Me too. It's simply good stewardship, just like what I learned wandering through, and wondering about, the mountains of North Carolina as a kid. Further, there is an opportunity for profit to be made. We will always need roads – at least until George Jetson's world (universe?) becomes a reality. And while some would be surprised, those in our industry wouldn't be - asphalt offers a lot.

THE GOOD NEWS

We have a pathway to get there! The National Asphalt Pavement Association, through their Climate Stewardship Task Force, published "The Road Forward" in 2022. The Road Forward documents a vision for achieving net zero carbon emissions for the asphalt pavement industry with a goal of achieving net zero by 2050 (more information at www.asphaltpavement.org/climate).

What does "net zero" mean? It does not mean absolutely zero emissions – that is likely impossible to achieve. It does, however, mean getting as close as possible to zero emissions in our materials selection, transportation, production, construction, impact in the use-phase, and end of life, and then offsetting the rest through methods that uptake carbon from the atmosphere.

The industry goals set forth by NAPA are as follows:

1. **Achieve net zero carbon emissions during asphalt production and construction by 2050.**
   In essence, the industry will work to understand and reduce the key drivers of emissions in asphalt production, on a net basis, and leverage existing or new emerging technologies such as warm mix asphalt and reclaimed asphalt pavement (or more efficient plants and equipment) in doing so.

2. **Partner with customers to reduce emissions through pavement quality, durability, longevity, and efficiency standards by 2050.**
   The asphalt industry will work with owner agencies to identify ways that technologies, specifications, and methods can help reduce the carbon emissions of asphalt pavements in direct or indirect ways without compromising performance.

3. **Develop a net zero materials supply chain by 2050.**
   To do so, the industry will need to work with materials suppliers and through methods such as balanced mix design to identify technologies and techniques that will achieve a net zero emissions supply chain.

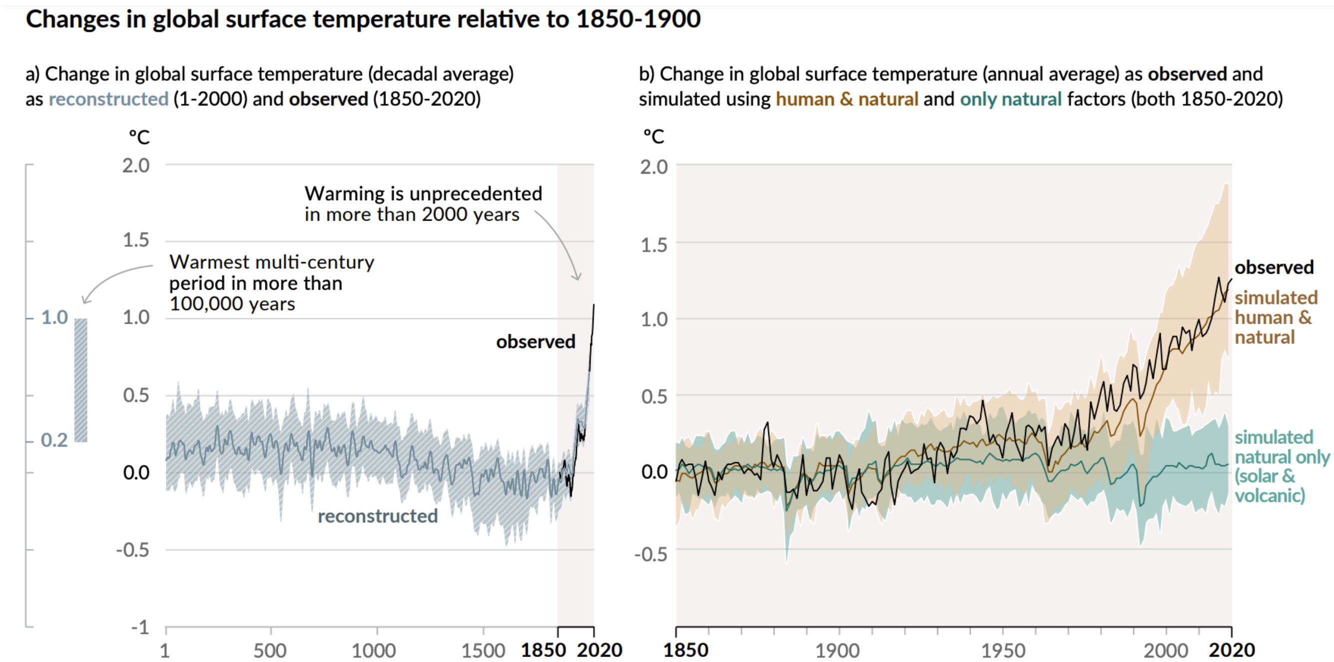

Figure 1. Changes in global temperature relative to 1850-1900, as published in the IPCC WGI Report.[1]

The left figure shows the change in global surface temperature and reconstructed temperature over the last 2,020 years and the right figure shows the difference between simulated natural (solar and volcanic) impact on temperature versus simulated human and natural influence (along with observed) from the years 1850-2020. While it is true that the earth's climate changes in cycles, the rate at which it is changing in the last 50-100 years is much more rapid. This is attributed in large part due to well-mixed greenhouse gases.

4. **Transition to electricity from renewable energy providers in support of net zero carbon electricity generation by 2050 and reduce electrical intensities.**
   It's no secret that the power generation industry is working toward net zero, which is great news, because we use power to operate asphalt plants, equipment, offices and labs (not to mention our homes). By capitalizing on available power opportunities (i.e., purchasing "green energy" when it's an option) and enhancing the efficiency of facilities, a move toward net zero emissions is achieved.

Moving toward net zero emissions will ultimately have an impact on our bottom line. There may be investments that have to be made, and change is incremental, but we, as engineers, producers, and materials suppliers need to step up to this design opportunity. We can make a difference for our environment, our neighbors, and make a profit (or save) along the way!

Contact Benjamin Bowers at bfbowers@auburn.edu for more information about this research.

1. IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

What's Happening With BMD Implementation?

Interest continues to build for using simple, yet robust balanced mix design (BMD) tests for mix design and production quality assurance. The full implementation of BMD will take several years as the asphalt community works to address several gaps and issues. This fall, NCAT will present a roadmap for implementation in a webinar followed by five regional in-person workshops as part of NCHRP 10-107. The roadmap was developed in collaboration with the FHWA and the University of Nevada, Reno.

More than 25 state DOTs have either begun implementation or have selected BMD tests and are in the process of benchmarking their current mixtures. NAPA's BMD Resource Guide is an outstanding resource on the current implementation status of BMD in each state as well as information about each test.

One of the motivations for implementing BMD is the opportunity to better evaluate the performance impacts of recycled materials and asphalt additives. Quite simply, volumetric properties are insufficient for assessing the impacts of recycled and innovative materials, leaving most highway agencies to rely on conservative limits for reclaimed asphalt pavement and ambivalence toward new additives.

Many DOTs view BMD tests as add-on requirements to a mix designed to meet traditional volumetric criteria. This strategy, referred to as Approach A in AASHTO PP 105, makes the mix design process even harder, drives up costs, and provides virtually no opportunity to innovate. Approach B in PP 105 also begins with a mix designed to meet all volumetric criteria but allows the final optimum binder content to be adjusted to meet rutting test and cracking test criteria. Therefore, Approach B has the same disadvantages as Approach A. The third BMD strategy, Approach C, begins with selecting an initial aggregate structure in accordance with AASHTO R 35 (Superpave mix design), but then puts meeting BMD performance criteria before volumetric criteria, and includes an important note that "highway agencies should decide which existing volumetric criteria could be relaxed or eliminated without sacrificing mixture performance." The notion to relax or eliminate traditional volumetric criteria is the realization that the BMD tests provide sufficient protection against rutting and cracking and the legacy criteria are merely a security blanket. Approach D in PP 105, referred to as Performance Design, is essentially full reliance on the selected BMD tests and criteria to yield a suitable mix design, and thus provides the best opportunity to optimize materials, additives, and proportions to simultaneously meet performance expectations and achieve more sustainable and economical mix designs.

Numerous states are benchmarking their current mixtures with the BMD tests they've selected. Some have expressed surprise at the range of results for their existing mixtures and have compared their results to criteria developed in other states. It is very important to realize that most BMD test results are sensitive to sample preparation. So, comparing BMD results from different organizations is not appropriate unless their mix handling procedures are carefully harmonized.

It is also important to note that benchmarking alone is insufficient to set criteria for mix design or acceptance. DOTs are strongly encouraged to confirm relationships between lab test results and field performance to build confidence that the test results are meaningful and needed to establish appropriate specification criteria. States that have been using BMD tests for many years may be able to mine data from their pavement management system's database to build lab-to-field performance relationships. However, for this approach, the field performance data of pavements across a state or region could be confounded by factors such as differences in the condition of underlying pavements, differences in traffic, differences in time and aging, etc.

A more direct way to establish reliable lab-to-field relationships is to build field validation experiments with test sections using mixtures that have a wide range of results for the selected BMD tests. This approach was used at the beginning of Superpave implementation with the construction of SPS-9 experiments in the Long-Term Pavement Performance (LTPP) program. A few states are currently developing plans for BMD field validation experiments. Building a field validation experiment takes a great deal of planning, attention to detail during construction of the test sections, and several years of traffic and environmental exposure to obtain discernable pavement performance differences that are needed to establish lab-to-field performance relationships.

The body of knowledge on several popular BMD tests continues to grow. For example, NCAT developed a new analysis technique for interpreting IDEAL-CT results to better understand how mix design factors affect toughness and the post-peak ductile-brittle behavior of a mixture. Recall that CT_{index} is calculated using Equation 1, where t is the specimen thickness, G_f is the fracture energy (area under the entire load-displacement curve, $|m_{75}|$ is the post-peak slope at 75% of the peak load, l_{75} is the displacement to 75% of the post-peak load, and D is the diameter.

$$CT_{index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \frac{l_{75}}{D} \qquad \text{Equation 1}$$

The new method of analysis uses an "interaction diagram" illustrated in Figure 1 to examine how a mix design change affects a mixture's CT_{index} through changes in toughness and its post-peak behavior. The fracture energy term, G_f, is plotted on the y-axis, and the ratio of l_{75} / $|m_{75}|$ is plotted on the x-axis. The interaction diagram includes a series of CT_{index} contour curves (dotted lines) that increase toward the upper right corner of the diagram. Increasing G_f and l_{75} / $|m_{75}|$ will yield a higher CT_{index} value. However, some mix changes may increase fracture energy, but cause a decrease in the l_{75} / $|m_{75}|$ ratio. As illustrated in Figure 1, increasing the asphalt content of mixtures typically increases fracture energy slightly and l_{75} / $|m_{75}|$ more substantially, providing a higher CT_{index}. Using a polymer modified binder instead of an unmodified binder typically results in a substantial increase in G_f and also a substantial reduction in l_{75} / $|m_{75}|$, which may result in no change to CT_{index} or a slight reduction. The interaction diagram provides a new perspective for interpreting IDEAL-CT results and understanding the impacts of mixture variables. Further information about the interaction diagram can be found in the 2022 AAPT paper "*Performance Characterization and Fatigue Damage Prediction of Asphalt Mixtures Containing Polymer Modified Binders and Recycled Plastics*."

Exploring quicker and lower cost rutting tests for use in quality assurance is another line of research. Two simple procedures are the high-temperature indirect tensile (HT-IDT) strength test and the Ideal-Rutting Test (IDEAL-RT). The HT-IDT uses equipment that already exists in most asphalt labs; the IDEAL-RT is like the HT-IDT except for a different loading fixture. The tests are conducted on specimens prepared like the IDEAL-CT and tested at a temperature based on the high pavement temperature for the project's climate. Preliminary data at NCAT shows that results from the two tests are very highly correlated and are also strongly correlated to the Asphalt Pavement Analyzer rutting test.

Interlaboratory studies have also provided data to establish within-lab and between-lab standard deviations for several popular BMD tests. These studies have also shown that in general, BMD test results are much more sensitive to sample preparation techniques than volumetric properties. As noted previously, detailed mixture preparation procedures must be established and followed for testing including mix conditioning, reheating, and laboratory aging to minimize differences in test results from lab to lab.

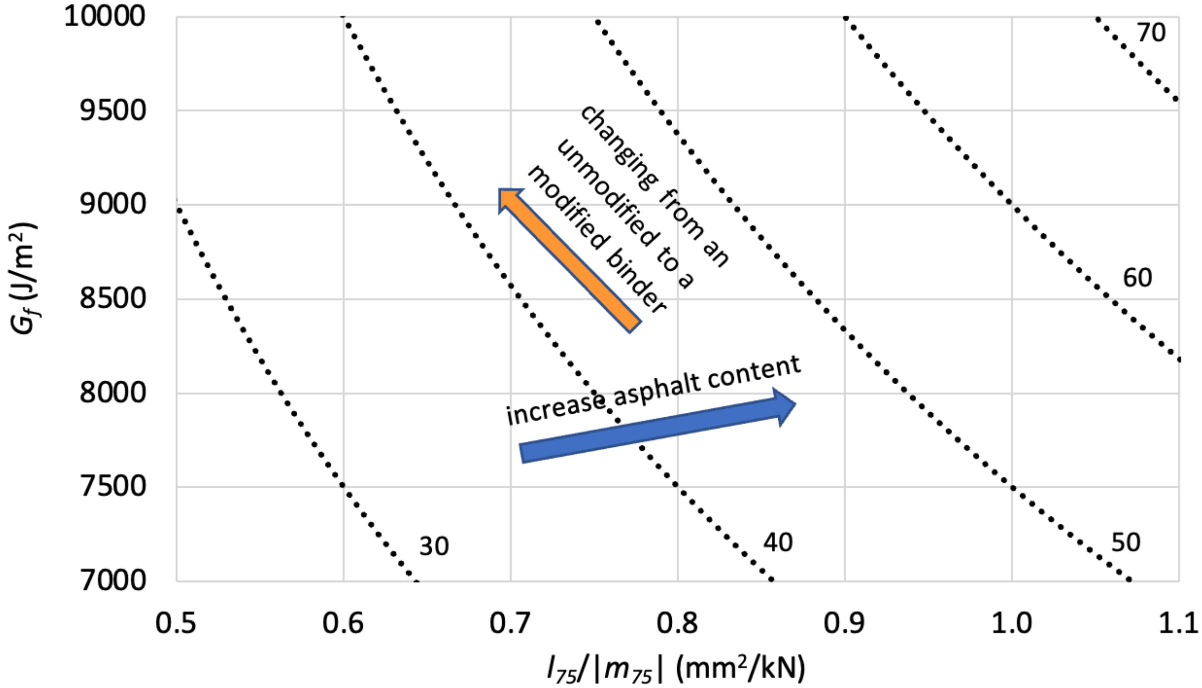

Figure 1. Ideal-CT Interaction Diagram

Recently, AASHTO R30 updated the short-term aging procedure of laboratory prepared mixtures to better simulate the asphalt aging and absorption that occur during mix production. Previously, R30 called for conditioning of mixture samples for four hours at the mixture's compaction temperature prior to compaction for mechanical property tests. The 2022 revision cuts the conditioning time in half to just two hours and standardizes the conditioning temperature as 135°C for HMA and 116°C for WMA. While this change helps timing logistics for mix design work, it adds a complicated wrinkle to using existing databases of test results that were established based on the previous four-hour conditioning protocol. For example, should DOTs that previously established criteria for Hamburg Wheel Tracking Tests based on four-hour conditioning now change the criteria to accommodate the new two-hour procedure in R30?

Long-term aging also remains an unresolved issue. Most asphalt researchers and practitioners acknowledge that a long-term aging protocol is needed for proper evaluation of cracking resistance of surface mixtures. Yet there is no consensus among several loose-mix and compacted-specimen aging protocols. Research funded by the National Road Research Alliance (NRRA) is underway to understand the impacts, advantages, and disadvantages of the different loose mix aging protocols and their correlation to field aging. A research needs statement on this topic is also making its way through the process for a possible NCHRP project for 2024.

The BMD implementation guide to be presented this fall will be a helpful resource for all stakeholders and provide a full picture of the tasks ahead for designing and constructing better asphalt pavements. When the dates are set, NCAT will promote the webinar and workshops through our social media platforms.

Contact Randy West at westran@auburn.edu for more information about this research.

Investigating Night Paving

Cold in-place recycling mixtures using engineered emulsions

When specifying night paving, some state agencies only allow foamed cold in-place recycling (CIR) mixes instead of emulsion CIR mixes. Emulsion CIR mixes of the 1980s and 1990s did not gain strength as quickly as foamed mixes and were stickier, increasing the risk of material pickup. This issue could be mitigated during daytime paving with sunlight and warmer temperatures expediting the emulsion break time. However, with cooler temperatures during night paving, foamed mixes are assumed to build strength faster and be less prone to raveling than emulsion CIR mixes.

New engineered emulsions are cationic systems designed to break quicker and build cohesion in the mixture. This new generation of emulsions offers appropriate mixing time, workability, moisture resistance, and superior strength compared to older CIR methods.

NCAT worked with Ingevity in January 2022 to investigate using engineered emulsions in night paving applications. The objective was to determine if engineered emulsion mixtures could demonstrate strength gain and raveling resistance at a similar rate as foamed mixtures in laboratory testing using short-term lab curing. Two engineered emulsions, including one containing a small amount of rejuvenator (engineered emulsion #1), were tested alongside a foamed CIR mix. All three mixtures used the same RAP source with 1% cement and had the same moisture and residual binder contents.

Despite having the same intended applications, the two methods (foamed and emulsion CIR) have different specifications. For example, foamed CIR mixes are typically required to pass a minimum indirect tensile strength (ITS) and tensile strength ratio (TSR) from indirect tension testing, while emulsion CIR mixes are tested for Marshall stability and retained strength from Marshall testing. The two tests are also performed at different temperatures. The difference in test methods makes head-to-head comparisons of the two CIR techniques challenging.

The two CIR methods were assessed head-to-head by comparing the engineered emulsions and the foamed mix using current industry-accepted tests, identical testing conditions, and, when applicable, acceptable specification criteria. A lower curing temperature of 10°C (50°F) was used to simulate the colder environment of night paving. Specimens were tested after four hours of curing to simulate strength gain a short time after construction as well as after the standard 72 hour cure for emulsion CIR mixtures.

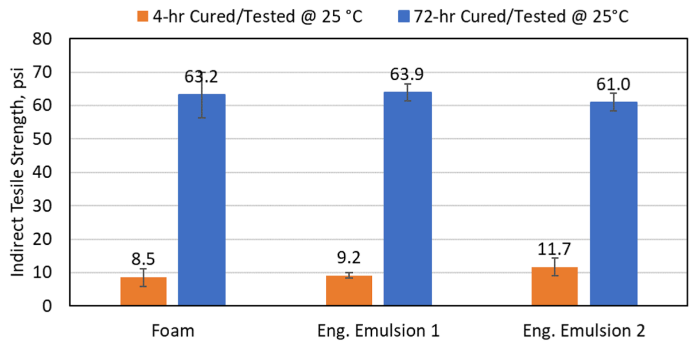

Figure 1. Comparison of Foam vs. Engineered Emulsion CIR Mixtures at 25°C

Figure 1 shows the dry ITS strengths at the two different conditioning times. All three designs had comparable strengths after being fully cured at 40°C for 72 hours and tested at 25°C. More importantly, the early strengths of the two engineered emulsions were slightly higher, but statistically equivalent to the foamed mixture after four hours of conditioning at 25°C. Furthermore, the ITS strengths of the two engineered emulsion mixes tested at 10°C after only four hours of curing were 100% and 45%, respectively, greater than the foamed mix ITS strength. The engineered emulsion designs demonstrated equal or better strengths in the fully cured and short-term cured conditions. Raveling potential of the three mixtures was determined using the rubber hose abrasion test following ASTM D7196-18. The engineered emulsions yielded lower mass loss (i.e., better raveling resistance) than the foamed CIR mix.

Contact Nathan Moore at nathan.moore@auburn.edu for more information about this research.

Targeted Overlays are "TOPS"

NCAT has been working on FHWA's Every Day Counts program initiative for Targeted Overlay Pavement Solutions (TOPS). Every Day Counts is a state-based program to encourage the adaptation of proven yet underused innovations to make our transportation system adaptable, sustainable, equitable, and safer for everyone. The TOPS project is included in the program's sixth round and seeks to improve safety, reduce overall life cycle costs, and increase the performance of our asphalt pavements.

The TOPS initiative highlights seven types of specialty asphalt mixes—

- asphalt rubber gap-graded
- crack attenuation mix
- enhanced friction overlays
- highly modified asphalt
- open graded friction course
- stone matrix asphalt
- ultra-thin bonded wearing course

NCAT's role in the project is to produce case studies, how-to documents, webinars, and workshops to assist state DOTs in learning about the specialty mixes and developing specifications for their use. We are continuing the work with our partners ARA and Weris as we move into the webinar and workshop phases.

The TOPS products are not new, but they may have limited use in some states. Below is a brief introduction to each mix.

ASPHALT RUBBER GAP-GRADED MIXTURES
Asphalt rubber gap-graded (ARGG) mixtures use an asphalt rubber binder that contains approximately 20% ground tire rubber. They are typically small NMAS mixes with a top aggregate size of 3/8-inch or ½-inch. The gradation of the aggregate is gap-graded to allow for a higher binder content and space for the rubber particles. These mixes are quite durable and have good resistance to rutting and cracking. ARGG mixtures are most often used as a surface layer, are placed 1.25 inches to 2.25 inches thick, and generally have good friction properties. These types of mixes are used in urban areas with considerable stop-and-go traffic, such as intersections.

CRACK ATTENUATING MIX
Crack attenuating mix (CAM) is a fine-graded mixture with a high-binder content that is placed as a half to one-inch-thick interlayer between the existing pavement and a surface asphalt layer to reduce reflective cracking. CAM design relies on the traditional volumetric mix design approach but also typically includes testing to assess rutting and cracking resistance. The mixes tend to be more expensive because of a high polymer binder content and the use of high quality aggregates. This cost is offset by reduced maintenance and longer life. CAM mixes have been successfully used on U.S. routes, interstates, and state highways, as well as farm-to-market roadways, and business highways as an interlayer.

ENHANCED FRICTION OVERLAY
An enhanced friction overlay (EFO) is a 4.75 mm nominal maximum aggregate size gap-graded mixture that uses calcined bauxite. Calcined bauxite is a hard, angular aggregate that provides excellent friction performance. Calcined bauxite is commonly used in high-friction surface treatments (HFST). EFOs use a polymer-modified asphalt binder and typically have a higher asphalt binder content than conventional mixtures.

EFO mixtures are best used in locations with high crash rates, such as curves, deceleration ramps, and intersection approaches. This mix is more expensive than traditional mixes because of the modified binder and the calcined bauxite, so it is typically placed quite thin with a total compacted thickness of ¾ inch. Studies indicate that EFOs have comparable friction values to HFST with the expectation of longer pavement life and reduced cost.

HIGHLY MODIFIED ASPHALT MIXTURES
Highly modified asphalt (HiMA) mixtures are produced using asphalt binder containing 7-8% polymer, typically styrene-butadiene-styrene. This polymer rate is more than twice what is used in conventional modified binders. The HiMA acts as an elastic reinforcement in the asphalt binder and improves mixture cracking resistance. In addition, considerable improvement to the rutting performance of HiMA mixtures has been documented.

HiMA mixtures have been used over a wide range of applications ranging from full depth to thin asphalt overlays. Although long-term pavement performance data for HiMA mixtures are not readily available in the field, promising performance in early pavement life has been reported and observed over multiple research cycles on the NCAT Test Track.

OPEN-GRADED FRICTION COURSE

Open-graded friction course (OGFC) is a gap-graded asphalt mixture with a high percentage of coarse aggregates almost uniform in size, resulting in a high percentage of air voids (usually 15-25%). Because of its safety and environmental benefits, OGFC has been widely used in the U.S., Europe, and Asia.

OGFC has an open-graded aggregate skeleton with interconnecting voids that allows rainfall to flow through to an impermeable underlying layer, and eventually to the pavement edge. Drainage of water from the pavement surface promotes the tire and aggregate interface contact and substantially reduces the likelihood of hydroplaning. OGFC is placed as a surface layer to maintain good friction in wet weather, reduce splash and spray and nighttime glare during wet conditions, enhance the visibility of pavement markings, and provide a smooth pavement.

STONE MATRIX ASPHALT

Stone matrix asphalt (SMA) is a tough and rut-resistant gap-graded asphalt mixture that relies on a stable stone-on-stone skeleton offering strength, a rich mixture of asphalt binder, and fibers and/or asphalt modifiers that provide durability. SMA was developed in Germany in the 1960s to provide a durable, rut-resistant wearing course that could withstand damage from studded tires for heavily traveled roads. SMA has been used in the U.S. since the 1990s in more than 40 states.

SMA mixtures are most often placed on pavements with heavy traffic, high-stress pavement areas, thin overlays, airfields, and racetracks due to the expectation of increased service life. SMA is more expensive than conventional mixtures, mainly due to higher asphalt contents, specifications for more durable aggregates, and inclusion of fibers as stabilizers. States have reported that SMA pavements generally have better long-term field performance than traditional mixtures.

ULTRA-THIN BONDED WEARING COURSE

Ultra-thin bonded wearing course (UTBWC) is a thin open-graded asphalt layer placed on a polymer-modified tack coat by a specialized spray paver that places the tack coat and the asphalt mixture in a single pass. UTBWC mixtures are often used as a pavement preservation method because they correct minor surface distresses and restore friction and smoothness. These mixes have been used in the U.S. since the early 1990s in a variety of traffic conditions in urban and rural areas.

More information can be found on the FHWA Every Day Counts webpage at https://www.fhwa.dot.gov/innovation/everydaycounts/.

Contact Adriana Vargas (left) at adriana.vargas@auburn.edu, Travis Walbeck (center) at travis.walbeck@auburn.edu, or Jim Musselman (right) at jim.musselman@auburn.edu for more information about this research.

NCAT Continues to Serve as NTPEP Test Laboratory

Since summer 2019, NCAT has served as the designated testing lab for the National Transportation Product Evaluation Program's (NTPEP) technical committee on warm mix asphalt (WMA). Through this collaboration, NCAT has evaluated 23 WMA and anti-strip additives (ASA) over the last three years and is evaluating eight new products in the current testing cycle.

In spring 2022, NTPEP expanded and renamed the committee to include the evaluation of recycling agents for recycled asphalt mixture applications, called the Asphalt Mixture Additives (AMA) committee. Adding the evaluation of recycling agents will significantly benefit state highway agencies, material suppliers, and asphalt contractors as the industry progresses toward the "The Road Forward" initiative to achieve net zero carbon emission asphalt pavements by 2050.

Using RAP and RAS in asphalt mixtures can provide significant economic and environmental benefits if the pavement meets performance expectations. However, mixtures containing high RAP/RAS contents can be susceptible to cracking and durability issues because the aged asphalt binder in RAP/RAS is stiffer and more brittle than virgin binder. Numerous studies have shown that adding a recycling agent has the potential to improve the cracking resistance of high RAP/RAS mixtures, but effectiveness varies greatly from product to product. Many state agencies have evaluated recycling agents through lab testing and field projects, but they generally lack a robust procedure to assess these materials for product approval purposes. This dilemma has a potential solution thanks to the NTPEP AMA committee.

Like the previous committee, the AMA committee offers work plans that are intended to compare a mix containing an asphalt additive (e.g., WMA, ASA, or recycling agent) to a control mix with the same mixture components and proportions to determine the additive's impact on mix properties. According to the AMA work plan, the evaluation of recycling agents is a five-step process–

1. Fingerprint the recycling agent using Reflectance-Fourier Transform Infrared Spectroscopy (FTIR).
2. Determine the dosage of the recycling agent by targeting a 6.0°C decrease in the continuous high-temperature performance grade of a PG 64-22 virgin binder.
3. Determine the continuous grade (per AASHTO T 313, T 315, and T 350), non-recoverable creep compliance (J_{nr}) and percent recovery (per AASHTO T 350), and Delta Tc (ΔTc) after 20 and 40 hours of PAV aging (per AASHTO TP 113) of a PG 64-22 virgin binder with and without the recycling agent.
4. Verify the volumetric properties of a 45% RAP mix design after adding the recycling agent.
5. Evaluate the rutting, moisture, and cracking resistance of the same 45% RAP mix design with and without the recycling agent using the Hamburg Wheel Tracking Test (HWTT, per AASHTO T 324), Indirect Tensile Asphalt Cracking Test (IDEAL-CT, per ASTM D8225), and Overlay Test (OT, per the modified Tex-248-F). The HWTT and OT will be conducted on specimens with short-term aging per AASHTO R 30, while the IDEAL-CT will be conducted on specimens at two aging conditions: 1) short-term aging per AASHTO R 30 and 2) long-term aging by further conditioning the short-term aged loose mixture for additional eight hours at 135°C.

NCAT researchers have been working on a 45% RAP mix design to evaluate recycling agents through the AMA committee. It is anticipated that NTPEP will open the first submission cycle for recycling agents in October 2023. In the meantime, NTPEP will open two submission cycles for WMA and ASA additives on October 1, 2022, and April 1, 2023.

Contact Fan Yin at f-yin@auburn.edu for more information about this research.

Pavement Bond Strength

What we know and don't know

There have been several research studies on measuring bond strength between asphalt pavement layers over the past twenty years. And while we've learned a great deal from that research, there are still some things we don't know. So, let's review what we do know – and what we don't know – about pavement bond strength.

We know that a good bond between asphalt pavement layers is essential to long-term performance. If pavement layers are not well bonded, stresses induced by traffic loads increase substantially throughout the pavement structure, leading to rapid accumulation of damage and a much shorter pavement life.

Slippage cracking is a common and easily detected bond-related distress. This occurs when the shear stresses at the interface of pavement layers exceed the shear strength of the bond and the pavement begins to slide on top of the underlying surface. Slippage cracks commonly appear at locations where horizontal stresses are the greatest– generally, where heavy vehicles accelerate or decelerate.

Slippage Cracking

Delamination

We also know that poor interface bonds can create other distresses such as delamination and cracking. Delamination occurs when a portion of the pavement layer is not adequately bonded to an underlying layer. When the pavement deflects vertically under load, the top layer separates further, and in some instances spalls out.

Poorly bonded asphalt layers also have a dramatic effect on fatigue cracking and damage to base and subgrade layers. All of the asphalt layers in a pavement structure are designed to act as one single layer. When a pavement is loaded, it bends and deflects, causing a range of complex compressive, tensile, and shear stresses through the pavement structure. In situations where the asphalt layers are not bonded, critical tensile stresses develop above the unbonded interface that can lead to "middle up" cracking. This scenario occurred at the NCAT Test Track in 2003.[1]

So, what is necessary to achieve a good bond between asphalt layers? First, the underlying layer should be clean and in fair condition. We know that scabbing, delamination, or severe cracking in the underlying pavement can negatively impact the bond and performance of the overlay. We also know the underlying surface needs to be clean. Studies have shown that a small amount of dust or grit on the underlying surface can significantly reduce bond strength, as the tack material sticks to the dust/grit and not the underlying surface.[2,3]

We've also learned the importance of a properly applied tack coat. We need to use the correct material, whether it's an asphalt emulsion or a hot-applied tack, and the correct application rate.[3,4] Application rates from distributors are notoriously incorrect, so a better approach is to measure the application rate directly using ASTM D2995 *Standard Practice for Estimating Application Rate and Residual Application Rate of Bituminous Distributors*. Another important thing we know about using an emulsion tack coat material is the need for the emulsion to properly break and cure. If the emulsion hasn't fully broken and cured, it will likely result in tracking by construction equipment and a loss of tack material– primarily in the wheelpaths where it's most needed. NAPA's Quality Improvement Publication 128 contains helpful information about emulsions, application of tack coats, and methods to prevent tracking.

So now that we've reviewed what we know about bonding of asphalt layers, let's consider some things we don't know. There's an old adage attributed to Lord Kelvin: "If you can not measure it, you can not improve it." This is appropriate for the bonding of pavement layers and leads to a few more questions. How should we measure bond quality? What is a suitable criterion, or in other words, how much bond strength is needed?

Let's start with how bond strengths are measured. In general, there are three basic modes of failure that can occur at the pavement interface: direct shear, torsional shear, and tension.[5] There are several different ways they're measured. NCHRP Project 9-40 identified 20 different in-situ and laboratory bond strength tests in its literature review.[3] In 2018, a survey conducted as part of NCHRP Synthesis 516 found that only 12 state DOTs conducted bond strength testing, and the majority used either direct shear or direct tension testing.[6] For direct shear, some states use AASHTO TP 114 (developed at the Louisiana Transportation Research Center), which uses a normal force and a shear force applied at 0.1 in./min. Some states use either the ALDOT/NCAT method or similar procedures that don't use a normal force and load at a faster rate of 2 in./min. Although testing with a normal force is more realistic, an NCAT study in 2005 showed the same ranking of bond strengths with and without normal force, so the recommendation was to use a simpler approach.[2] The bottom line is that there is no consensus on the best approach to measure bond strength.

An important question for any test is variability. In a perfect world, test methods go through a ruggedness study to determine the impact of permitted variations in testing conditions on the results, such as loading rate, test temperature, core diameter, etc. Once those variables are narrowed down, variability of the test should be determined through an interlaboratory study. This determines the allowable within- and between-laboratory differences for test results. A 2009 interlaboratory study conducted by a European organization (RILEM) determined that approximately 12% of the within-lab coefficient of variability (COV) for the European Standard direct shear bond strength method (similar to the NCAT method) is attributable to sampling and testing. Recent bond strength testing from seven projects conducted at NCAT found that COVs ranged from approximately 38% to 63%, but this included materials and construction variability. In other words, the variability of bond strengths from a project is affected by factors such as surface cleanliness, scabbing, and residual tack coat remaining on the surface. COVs of the RILEM study and NCAT work suggest that field conditions cause more variability than the test method.

Another question is how much bond strength is required. A follow-up project to NCHRP Project 9-40 recommended a minimum bond strength of 40 psi when using the Louisiana Interlayer Shear Strength Test.[7] NCAT recommended a minimum bond strength of 100 psi (based on noted distresses in Alabama) when using the direct shear method developed at NCAT.[2,8] Some states have established their own values based on testing areas with pavement slippage. There is also a wide range of required strengths for direct tension tests.

While it's important to have good interlayer bond strength, more work is needed to sort out what test should be used, how much variability is in the test, and what the minimum bond strength should be. If those questions can be answered, highway agencies and the asphalt paving industry can work together to eliminate poorly bonded pavements as a cause of failure.

Contact Jim Musselman at jim.musselman@auburn.edu for more information about this research.

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New Faces at NCAT

Chen Chen, Research Engineer

After completing his undergraduate and master's degrees in his native China, Chen Chen received his PhD from Auburn University before spending a year working in the asphalt industry. He then returned to NCAT as a post doctorate researcher, and now continues his journey as a research engineer.

Chen's research focuses on recycled materials, polymers, and additives, and how they can be used to improve sustainability in the asphalt industry. He appreciates the opportunities his new role at NCAT affords him. "Here at NCAT, I have the chance to get involved in projects all over the country. I can continue working and building knowledge while working with great people."

Chen enjoys not only the work, but also the working environment. "I studied here, and I really feel like NCAT is a family, so it made me want to come back."

When he isn't working, Chen enjoys running, hiking, reading, watching movies, and hanging out with friends.

Suri Gatiganti, Research Engineer

Suri Gatiganti came to Auburn University as a PhD student in 2018. After working as a post doctorate researcher, he's taken on a new role as a research engineer. Suri is continuing the research he began as a post doctorate exploring life cycle assessment and making connections with those who work on sustainability.

Suri is excited to continue his career at NCAT and enjoys the hands-on experience writing proposals and supporting principal investigators. "Once I got here, I saw all the implementable research that NCAT does. I really like that about working at NCAT."

Suri enjoys being part of the NCAT family and is thankful for the connections he has made so far. "I like working with people who will mentor me and help me further my career."

In his free time, Suri plays badminton and racquetball, and was a member of the Auburn University cricket team. He enjoys spending time with friends locally, keeping up with friends back home in India, and attending Auburn football games.

Biswajit Kumar Bairgi, Postdoctoral Researcher

Biswajit Kumar Bairgi completed his PhD in Civil Engineering at the University of New Mexico in 2021 and joins NCAT as a postdoctoral researcher. "I read a lot of work from NCAT while I was working on my PhD. I found that this is one of the best places to work in my field. I am very happy to join the NCAT family."

Since joining NCAT, Biswajit has worked on several projects, including the Balanced Mix Design Resource Guide with NAPA, CAPRI database, delamination of airfield pavement, high recycled materials in asphalt mixture, and developing new grants. He discovered his passion for engineering as an undergraduate student and reveled in the chance to work on an airfield paving job in his native Bangladesh.

Outside of work, he is passionate about music, playing guitar, piano, and percussion, and has a YouTube channel where he regularly posts cover songs. He cites The Beatles, Pink Floyd, and Dire Straits as a few of his favorite bands.

Anita Robinson, Assistant Director, Operations and Planning

Anita Robinson joins NCAT after spending 19 years at the Auburn University College of Agriculture. She's excited to join the NCAT family and to work with people who are excited about their work. "I wanted to work with people who were passionate about what they do. I noticed that immediately when I came to NCAT."

In her role as assistant director, operations and planning, she oversees all the financial operations at NCAT, from monitoring multimillion dollar awards to payroll and paying vendors. She sees her job as a way for engineers to focus on their work and not have to worry about the red tape that comes along with accounting.

When she isn't at work, Anita enjoys watching old movies, reading, and traveling around the southeast.

Kyle Lubinsky, Communications and Marketing Specialist

Kyle Lubinsky comes to NCAT from Johns Hopkins University where he worked as a digital communications specialist. While there, he focused on social media, writing, and building websites.

He's excited for a new opportunity to be creative. In his role at NCAT, he'll handle copy editing, design work, social media, and putting together newsletters. "I'm enjoying working on a diverse group of projects with a passionate group of people."

Outside of work, he enjoys running, biking, hiking, fishing, going to concerts, and spending time with friends. He looks forward to going to Auburn football and baseball games.

Specification Corner

FLORIDA DOT
Based on contracted research with Texas A&M Transportation Research Institute, SP-9.5 mixtures of various aggregate types were shown to be just as rut resistant as SP-12.5 mixtures and will now be allowed to be used in FDOT's highest traffic level roadways.
We've increased the minimum AC content in open-graded friction courses to 6.5% for Florida limestone mixtures and 6.0% for granite mixtures.
We're limiting the maximum storage temperature for polymer modified binders to 355°F.

ILLINOIS DOT
IDOT is adding a special provision allowing designers to specify longitudinal joint sealant in half-width applications such as inlays and narrow stage construction.

INDIANA DOT
INDOT has incorporated spray pavers for use with dense-graded HMA into our paving program. We are targeting interstates, 4-lane divided highways, and freeway-like roadways. This allows us to use a polymer modified emulsion without it being tracked away by construction traffic.

MONTANA DOT
We just published a significant revision of our Section 400 - Plant Mix Pavement specification https://www.mdt.mt.gov/other/webdata/external/const/specifications/2020/SPEC-BOOK/2020-SPEC-BOOK-V3-1.pdf. Main revisions involve removing the restriction of sampling the first 100 tons of mix (since we still pay full price for that material) and an update and clarification to our Hamburg field acceptance specification. Originally, the difference between 12 mm and 13 mm rut depth meant full pay or remove and replace. So, we've been working on a tiered level of acceptance based on binder grade, rut depth, depth of pavement, and traffic level (bike paths vs. interstates).

We're also working on implementing MSCR and had a kickoff meeting in the spring, but we need to follow up with our pavement design folks to make sure everyone is on the same page, update the pavement design guide, and then roll out the specification via special provision in contracts– hopefully next season. We had our first job with MSCR binder via change order, and all went well for the small quantity it represented.

Asphalt Forum

NCAT invites comments and questions submitted to Kyle Lubinsky at kal0105@auburn.edu.

We continue to adapt to dwindling gravel sources, as permitting and volume are causing us to explore new options. As such, we're seeking guidance on quarry/ledge rock and how to specify/accept it. In one situation, a contractor with a quality (anecdotally) limestone source did not bid a job because they claimed to meet all specifications except a 75 gyration mix design. In another situation, we had a contractor use a limestone source that met all durability requirements, as well as a 75 gyration design, but it performed poorly in the field. What we found was the aggregate didn't completely degrade, but "resized" in the plant so the 3/4" NMAS design ended up being a 1/2" NMAS (more or less). Any information or insight on how to guard against that phenomenon would be helpful.

-Oak Metcalfe, Montana DOT

The following responses were received to questions shared in the previous issue.

> Where do you take the longitudinal joint (density) cores? Our current specification requires them to be taken from the center of the visible joint—the local contractors continually fight us on this stating that it should be taken over the top of the "wedge" created by the safety edge. Has there been any recent research on this topic?
>
> -Michael Stanford, Colorado DOT

BRIAN HILL, ILLINOIS DOT
Longitudinal joint density testing is completed in Illinois at 4 inches from the longitudinal joint to the near edge of the core barrel (assuming density testing is completed using cores). If longitudinal joint sealant (a.k.a. Void Reducing Asphalt Membrane – VRAM) is present at the longitudinal joint, IDOT does not complete longitudinal joint density testing.

RICK BRADBURY, MAINE DOT
From MaineDOT's specification: "For vertical longitudinal joints, cores shall be taken directly centered over the construction joint. For notch-wedge longitudinal joints, the cores shall be cut directly over the center of the tapered portion of the wedge."

OAK METCALFE, MONTANA DOT
I don't know of any research, but here is an excerpt from our specifications dealing with this issue: "The joint area is defined as the tapered area at the overlap of the hot and cold lanes. Furnish the Department with a 4-inch or 6-inch core of the compacted joint for every 4000 feet (1219 m) of joint constructed, and at least 3 per project, at locations directed by the Project Manager. Center the core within the tapered area to include both the hot lane and cold lane. Mark the core as directed." So, it appears we agree with your contractors. If you center the core on the visible joint, you get significantly more volume of "cold" mix than "hot" mix and a thinner wedge of "hot" mix, lending to potential edge conditions, for lack of a better term.

CHARLIE PAN, NEVADA DOT
NDOT's joint density tests are not required on unconfined edges (like safety edge). Joint density tests are completed on the hot side of the mat (within 6 inches).

STEVE HEFEL, WISCONSIN DOT
WisDOT uses correlated gauges centered 6 inches off the centerline joint. Both sides of the joint are tested.

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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) at 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.