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Asphalt Technology News

Features

Pavement resilience

Balanced mix design

Rejuvenator evaluation on the Test Track

Testing for success

Density profiling systems for compaction

Thin overlays for pavement preservation

Life cycle cost analysis residual values

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Contents

Message from the Director

Come Join CAPRI

If you are like me, you may have asked yourself, What are the most important things we can do to achieve more sustainable asphalt pavements? Sustainability considers the intersection of economic, environmental and social concerns. Although it is definitely a big picture concept, it is an achievable goal. Many practices and technologies can be adopted to improve sustainability, and it's important to think about the big picture as we make decisions to help us move toward these priorities.

The Consortium for Asphalt Pavement Research and Implementation (CAPRI) is a new forum that will engage all stakeholders to discuss and develop priorities for research and implementation activities that advance asphalt pavement technologies. Whether you think more attention should be focused on sustainability, improving construction quality, advancing automated testing, better utilization of pavement preservation treatment options or something else, CAPRI will be the place where you can be part of the debate and influence decisions through open discussions among all stakeholder groups.

The foundation for CAPRI is just getting established. Currently, 15 state DOTs and 11 other stakeholder organizations including contractors, associations, materials suppliers and academia have officially joined with others to come. Each member organization is required to put skin in the game by contributing a small annual fee.

NCAT will provide management for the consortium. An initial executive committee has been formed and is meeting to establish bylaws, policies and plans for the first meeting, we hope this fall. Once the pandemic is behind us, plans are to have two meetings per year at locations facilitated by member organizations. It is expected there will be four subcommittees within CAPRI that align with the AASHTO COMP technical subcommittees related to asphalt pavements.

Another one of CAPRI's goals is to provide technical guidance on current and evolving issues. Again, through open discussion of technical issues and working towards a consensus, we hope to be able to develop guidance on how to deal with those issues if they can be addressed with clarifying text or recommendations for small studies that address gaps in the existing body of knowledge.

If your organization is interested in having a seat at the CAPRI table, please check out ncat.us/research/capri or send an email to capri@auburn.edu and we will follow up with whatever information you need. We're all in this together, so let's get to work.

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

What Does it Take to be Resilient?

Resilience is a word that is now circulating amongst transportation agencies, industry, academics and policy makers. But what does this word mean, and what are the implications for the future of our roads?

The Federal Highway Administration defines resilience in FHWA Order 5520 as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to and recover rapidly from disruptions."[1] It is no secret that our infrastructure has been tested, especially as it has aged. Just this past year alone, the U.S. experienced a record-breaking hurricane season with 30 named storms and 12 landfalling storms.[2] On the west coast, California experienced the worst wildfire season in its modern history, with the August Complex fire burning a swath of land estimated to be the size of Rhode Island.[3] The middle of the country is no better off – in 2019, Iowa and Nebraska experienced the second 500-year flood in 10 years, putting many roads underwater. Other climate disruptions include drought and heavy precipitation, tornadoes, record breaking heat or cold like that experienced in Texas in 2021 and rapid temperature changes, all of which can have a detrimental impact on our pavements.

RESILIENCE AND THE CHALLENGE IT PRESENTS

One of the big challenges facing pavement infrastructure is flooding. Agencies have expressed concerns about flood inundation and its impact on pavement performance. Once a pavement base becomes saturated, pavement strength is reduced and materials may be compromised. This is already becoming problematic along the east coast due to sea level rise and storm surges. Another challenge is extreme temperature – temperature swings can cause rutting, cracking and buckling of pavements. Drought followed by heavy precipitation, especially in areas with expansive clay, can lead to major roadway deterioration. Further, while a disruption may directly impact a portion of pavement, cascading events can create indirect impacts on surrounding infrastructure such as excessive loading of overweight (but permitted) debris removal trucks on pavements after a tornado or hurricane or the rerouting of tractor trailers on local roads due to a main route being compromised by flood waters.

WHAT NOW?

What are we to do with this predicament? We must adapt, and fortunately the resilience lexicon has a word for that: adaptation. FHWA Order 5520 defines adaptation as "an adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects."[1] A non-infrastructure example is our collective resilience to the challenging work conditions presented to us this past year by the COVID-19 pandemic. While the world momentarily stopped, we couldn't stay in "pause mode" forever. So, we adapted. One such adaptive strategy is the leveraging of web-based conferencing tools like Zoom, WebEx and the like. Not only do we meet microphone-to-microphone and camera-to-camera to discuss business, but we also virtually conduct educational coursework, webinars and even conferences. We adapt.

It is important to recognize there is no single adaptive strategy that will work for all situations. Decision makers and designers need to identify the key vulnerabilities of the highway, assess the risk of a disruption and then decide what adaptive strategies to employ. Often, the first thought is to "harden" or strengthen the infrastructure so that it is protected and can withstand nearly any disruption. This is a technically effective adaptation strategy, but it can also be cost prohibitive. Adaptation through modification is another approach that can be taken – using materials and techniques to harden the infrastructure to a certain degree while recognizing that the infrastructure has a potential to be disrupted. Another adaptive strategy is to simply accept and plan, meaning accepting that failure *may* occur, and developing plans *now* between agency and industry to rapidly repair the road. Finally, one can accept that it may make the most sense to abandon the route altogether, using alternative routes or relocating the community.

THE TOOLS WE HAVE, THE TOOLS WE NEED.

The good news is asphalt pavements already have several resilient attributes and tools available, though we don't usually think of them through the lens of resilience. For example, it is no secret that a benefit of asphalt is its rapid constructability. While usually considered a benefit for minimizing road closure, among other applications, if a roadway is compromised due to an earthquake

or flood, asphalt can be used to rapidly repair the road so that people and goods can begin to move again. Asphalt is also 100% recyclable, which is particularly useful if aggregate or binder supply chains are disrupted by an event. Warm mix asphalt technology can be used not just for an environmental benefit, but also to pave in cold-weather response situations and to increase haul distances during a disruption. While asphalt materials are already adaptable to changing conditions like traffic, polymers and other binder or mixture additives can be used to add structure and manage climate variability.

Hurricane Michael damage on SR-30 (US-98) in Franklin County, Florida. Photo courtesy of Kevin Wall.

Perpetual (long-life) pavement design is a method used to design a pavement thick enough to carry long-term structural loading without overdesigning, and it can be used for critical evacuation routes or potentially pavements that are subject to flood inundation. Standard maintenance overlays can also be leveraged by minimizing the amount of asphalt that needs to be milled, ultimately increasing the pavement structure's thickness at approximately the same cost. Porous asphalt pavements are designed to handle water, making them a good option for managing large precipitation events. Deep rehabilitation methods such as full depth reclamation with an asphalt overlay are used to enhance the structural capacity of a highway at a reduced cost. This can also be done to harden roads that are now subject to flood inundation or potential rerouting of traffic. These are but a few of the tools we already have; we simply need to use "resilience thinking" to apply them as appropriate.

In conclusion, research efforts still need to find ways to incorporate future climate models into our design and material selection methods as opposed to the currently used historical climate data. Further, materials, pavement structures and new innovative adaptation strategies should be investigated to continue paving the way to a more resilient transportation infrastructure.

For more information on this topic, read the forthcoming NCAT Report 21-02, Asphalt Pavement: A Critically Important Aspect of Infrastructure Resiliency.

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

1. Federal Highway Administration. FHWA 5520. December 15, 2014. https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm
2. National Oceanic and Atmospheric Administration. Record-breaking Atlantic hurricane season draws to an end. November 24, 2020. https://www.noaa.gov/media-release/record-breaking-atlantic-hurricane-season-draws-to-end
3. California Department of Forestry and Fire Protection. 2020 Incident Archive. https://www.fire.ca.gov/incidents/2020/

Implementation Spotlight

Balanced Mix Design for Alabama Counties

Purchase order mixes for Alabama counties are typically bid using the Alabama DOT's (ALDOT) mix specifications but are not subject to the same rigorous construction quality testing as other projects. Counties often do not have an inspection presence at the contractor's plant, and there is no formal mix quality documentation requirement.

Performance issues have been noted on some recent projects, and in the summer of 2019, engineers from Geneva and Houston counties in the southeast corner of the state reached out to NCAT for advice on the best way to improve their purchase order mix quality. A state motor fuel tax increase had been passed that gave Alabama counties greater flexibility for asphalt mix specification requirements. Initially, the counties asked about eliminating reclaimed asphalt pavement (RAP) to improve mix quality; however, NCAT suggested using a simplified balanced mix design (BMD) specification to ensure good rutting and cracking resistance and allow for higher RAP contents as long as the performance testing requirements could be satisfied during construction.

Research to validate laboratory performance testing was initiated at NCAT's Test Track in 2015. The Cracking Group experiment was funded by numerous state DOTs and FHWA to assess which cracking tests have results that correlate well with field performance. Through this experiment, five tests provided favorable correlations to measured cracking performance on the track.

The simplicity of sample preparation and the ability to utilize existing equipment and generate results quickly made the IDEAL-CT test an attractive choice for use during construction of purchase order mixes procured by Alabama counties. Where the IDEAL-CT test utilizes the shape of an indirect tensile (IDT) load-deformation curve to detect potential mix brittleness at 77°F, the same testing equipment and samples can be used to screen a mix for poor rutting performance using the peak load at 122°F (i.e., hot-IDT testing). Mixtures can be screened for both cracking and rutting performance during construction within approximately four hours, which easily facilitates morning and evening testing. Based on proven performance on the track, the minimum CT_{Index} from the IDEAL-CT test was set at 50 and the hot-IDT minimum IDT strength was set at 17 psi for plant produced mixtures in the proposed specification for Alabama counties.

Local asphalt contractors responded to the specification change enthusiastically. When the bid was advertised, their first step was to evaluate their existing Superpave mixes to assess the need for mix design changes and opportunities to improve sustainability. They generally observed low CT_{Index} values and high hot-IDT values, noting that mixes utilizing lower RAP mixes exhibited higher CT_{Index} values. They iteratively adapted their Superpave mixes to meet the new cracking and rutting test requirements. The resulting blends resembled the Marshall mix designs that were used in Alabama until the time of Superpave implementation. These new BMD mixtures contained 35% RAP (compared to 20% RAP for the Superpave mix designs) and higher total binder contents of between 0.5% and 0.75% asphalt.

Contractors reported a longer time to obtain BMD results, with typically a full day to obtain a single data point. They also reported the need for more attention to detail with respect to times, temperatures and technologies. BMD results were found to be sensitive to conditioning time and a lack of precise temperature control that in one case necessitated an oven upgrade. A significant observation from the iterative mix design effort was the impact of RAP binder quality on mix performance results, noting that volumetrics can be blind to this effect. In the end, it was possible to increase to 35% RAP, but some RAP stockpiles that would have been used for Superpave mix designs did not work well in the BMD mix designs.

The new specification also resulted in significant testing changes during mix production. Contractors were required to determine both CT_{Index} and hot-IDT strengths. Using the contractor's mix design as a starting point, production mix proportions necessary to satisfy performance results were established via a test strip. Mix performance testing was conducted within the first 100 tons of mix shipped each day, and testing was repeated if a mix was still being shipped after five hours and the total quantity shipped for the day exceeded 500 tons. Failing results necessitated retesting, while a second set of failing results demanded a new test strip to

reestablish mix proportions and passing results.

Although acceptance was based on BMD results, contractors also needed to know total binder content, maximum theoretical specific gravity, gradation and air voids. This significant increase in production testing approximately doubled the time to generate lab results, making time and oven management more important in laboratory workflow management.

The importance of RAP quality was a significant factor in specification compliance with production mix. Higher CT_{Index} values (increasing by 8 to 25) and lower hot-IDT strengths (decreasing by 0 to 6 psi) were typically observed during construction compared to the mix designs. Paving crews reported that the new balanced mix designs were more workable in the field and generally took less compactive effort than Superpave mixes to achieve the required mat densities.

The counties using this balanced mix design specification have been very pleased with cost, construction and early performance of mixes, even with much higher RAP contents. Although they had an option to continue to utilize Superpave mixes, they used the new specification for the vast majority of their purchase order paving work by the end of 2020. The bid price was 6% lower than comparable Superpave mixtures within the same work year, and it is expected that the overlays will have a longer service life based on observations during laydown and early performance assessments.

A Midsouth Paving crew working in Eufaula, Alabama.

Contractors are enthusiastic because this specification provides for competitive innovation without traditional volumetric boundaries. The two counties plan to use it again for the 2021 paving season, and additional counties have plans for adoption. ALDOT is observing the county experience closely and plans to utilize their experience in the continued development of a balanced mix design specification for higher level traffic state projects as well as for county projects that require ALDOT oversight. In addition to monitoring the annual purchase order mix procured by Alabama counties, ALDOT's long term plan for balanced mix design implementation includes shadow projects and trial projects at the state level.

Table 1. Mix Design and Plant BMD Data for an 8,000-ton County Road Project in South Alabama

9.5 mm	Total Binder Content (Combination of Virgin and Recycled Materials), %	CT_{Index}	Hot-IDT, psi
Lab Mix Design	6.40	50	38
Average	6.23	73	32
Standard Deviation	0.13	18.3	13.6

Contact Buzz Powell (left) at buzz@auburn.edu, Alex Murphree (center) at Alexander.Murphree@midsouthpaving.com or Justin Barfield (right) at justinbarfield@genevacounty.org for more information about this project.

Lessons Learned from the First Mixture Rejuvenator Evaluation on the Test Track

Several methods have been investigated to reduce potential adverse effects of reclaimed asphalt pavement (RAP) binder on the field performance of asphalt mixtures. One method is to use rejuvenators to restore rheological properties of oxidized asphalt binders in RAP mixtures. These rejuvenators can be petroleum-based or bio-based oils formulated to restore the balance of maltenes that were lost or transformed to asphaltenes in the oxidized RAP binder.

One of the bio-based rejuvenators commercially available is Delta S, which was developed by the Warner Babcock Institute for Green Chemistry and later commercialized by Collaborative Aggregates, LLC for use in recycled asphalt mixtures. This bio-based rejuvenator was used to produce an asphalt mixture with recycled materials placed in the surface layer of Section N7 on the NCAT Test Track, and the test section was trafficked for field performance evaluation from 2015 through 2021. Its performance was compared with that of Section N1, which was the control section for the Cracking Group experiment.

The two surface mixtures were designed to meet the volumetric requirements in AASHTO M323. The main difference between the two surface mixtures was that while the N1 surface mixture was designed with 20% RAP, the N7 surface mixture was designed with a higher recycled content and Delta S to counter the effect of the high recycled content on the mixture's cracking resistance. The Hamburg Wheel Tracking Test (HWTT) and Illinois Flexibility Index Test (I-FIT) were conducted on short-term aged specimens to verify their similar rutting and cracking performance. The two mixtures were paved on the same pavement structures with 7 inches of asphalt concrete. The surface layer of N7 was originally built on August 6, 2015 using a 9.5 mm mixture containing 20% RAP and 5% post-consumer recycled asphalt shingles (RAS). Delta S was added to the virgin PG 67-22 binder at a dosage of 10% by weight of the recycled binders available in the RAP and RAS materials.

Truck trafficking of the sections began in the fall of 2015. Cracking on Section N7 was first observed in late January 2016 after 1.4 million equivalent axle loads (ESALs). Cores extracted from the section indicated that the cracks were caused by delamination between the surface and intermediate asphalt layers.

Section N7 was repaired by milling and repaving the same mixture with an increased tack rate to improve the interlayer bond strength between the surface and underlying layers on April 15, 2016. After just a few hours of fleet operations, a slippage failure was observed in the section.

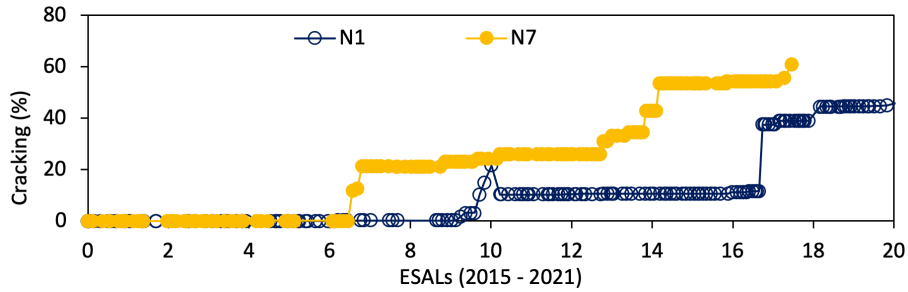
A forensic evaluation of the surface mixture found that the delamination was not caused by a weak bond strength or insufficient tack coat, but in fact was due to reduced stiffness and tensile strength of the surface mixture. This evaluation included field cores and specimens prepared using (1) laboratory-prepared mixtures that were unaged, aged for two hours at 135°C, aged for four hours at 135°C and (2) reheated plant mix.

The surface mixture produced on April 15, 2016 had been laid and compacted without any silo storage, as it was produced and hauled to the Test Track (approximately 10 minutes away) for immediate paving. Because of the short haul, the interaction between Delta S (blended with the virgin binder) and the recycled binder, especially in the RAS, may not have been completed, leaving a higher proportion of Delta S in the virgin binder than originally intended. This caused a decrease in stiffness and tensile strength, leading to the shear failure in the surface mixture.

Section N7 was rebuilt by removing all asphalt layers and repaving from the aggregate base up on May 12, 2016. The redesigned surface layer for N7 contained 35% RAP (no RAS) and Delta S injected into the PG 67-22 binder supply line at a target rate of 5% by weight of RAP binder. To give the rejuvenator time to interact with the RAP binder, the mixture was held in a silo for two hours before being transported to the Test Track.

Figure 1 compares the field cracking performance of N1 and the May 2016 rebuild of N7. Section N1 had already carried approximately 2.5 million ESALs when N7 was rebuilt. Thus, approximately 17.5 and 20 million ESALs were applied to Sections N7 and N1, respectively, by January 2021.

Figure 1. Test Track Cracking Performance for Sections N1 and N7



Cracking (only 0.1% of the lane area) was first noted in N7 on October 24, 2016 after 2.1 million ESALs. For N1, cracking (approximately 0.2% of the lane area) was first observed on March 6, 2017 after 6.2 million ESALs. Cracking in N7 jumped from 0.1% to 21.3% in October 2017 after approximately 6.6 million ESALs. For N1, cracking also increased significantly from 0.2% to 10.2% in October 2017 after 9.7 million ESALs. Cracking typically progresses quickly in spring (around March) and fall (around October) seasons at the Test Track. However, the cracks were very tight (less than 1 mm opening) near-surface cracks, as shown in Figure 2.

Figure 2. Close-up of Hairline Cracks in Sections N7 and N1

Cracking in N1 increased slightly from 10.3% at the beginning of the 2018 research cycle to 11.5% in March 2020 after 16.6 million ESALs. It then jumped to 37.4% the next month after 16.9 million ESALs. Cracking then gradually increased up to 45.8% at the end of the 2018 research cycle in February 2021. However, the severity of the N1 cracks remained very low.

Cracking in N7 did not increase again until March 2019 after 8.9 million ESALs when it increased slightly to 22.9%. Cracking increased gradually in 2019 up to 33.1% in December after approximately 12.7 million ESALs. No increase in cracking was observed between December 2019 and February 2020 after 13.3 million ESALs.

The cracks observed in N7 in January 2020 were still low severity, as shown in Figure 3a. In some areas, the cracks became connected and fines could be seen along some of the connected cracks (Figure 3b). To further evaluate the cracks observed in N7, cores were extracted from the areas with the connected cracks. As shown in Figure 3c, these cracks were full depth and are believed to have initiated at the bottom of N7 and propagated to the surface.

Figure 3. (a) Section N7 as of January 8, 2020 (b) Closeup of Hairline Cracks in the Wheel Paths, (c) Field Core Confirming Bottom-Up Cracking

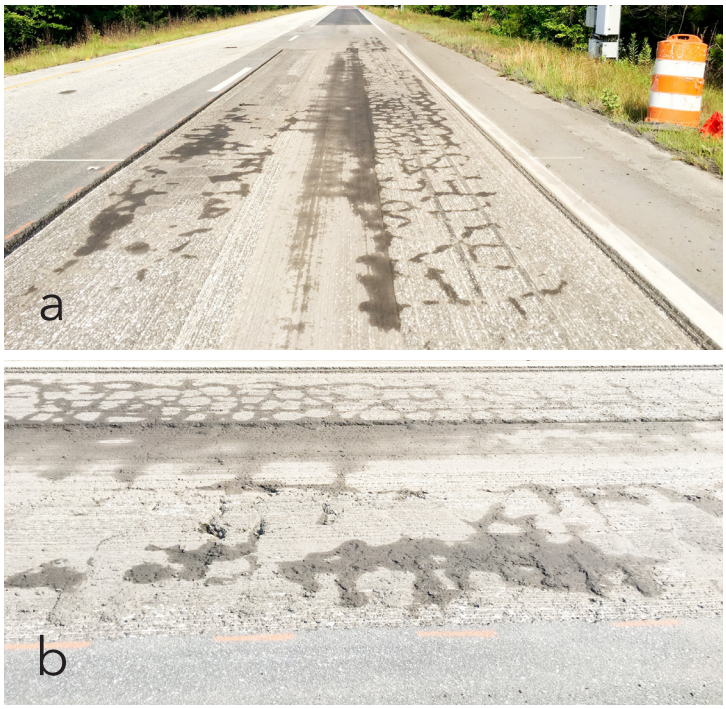
After consulting with the sponsor, Delta Mist spray-on rejuvenator was applied to the cracked surface of N7 at a 0.08 GSY rate on February 21, 2020 (Figure 4) to evaluate if the spray-on rejuvenator could help extend the life of an asphalt pavement with bottom-up fatigue cracking. However, cracking progressed significantly the week after Delta Mist was applied. Cracking in N7 increased from 33.1% right before the Delta Mist application (13.3 million ESALs) to 53.4% in April 2020 after 14.2 million ESALs. The addition of Delta Mist presumably softened the distressed asphalt structure and accelerated the rate of bottom-up cracking (Figure 5).

In summary, lessons learned and key findings from the field evaluation of Delta S and Delta Mist rejuvenator products on the Test Track include the following:

- Delta S should not be used with southeastern post-consumer RAS without an adequate reaction time during production. Without an adequate reaction time with aged binders, Delta S may excessively soften the virgin binder, potentially leading to premature failures.
- Short-term aged I-FIT results suggested similar cracking performance for the 35% RAP mix with Delta S and the control mix with 20% RAP. However, cracking appeared earlier and progressed slightly quicker for the 35% RAP mix with Delta S at the Test Track. The largest increase in cracking for both sections occurred in October 2017 (fall season) for the 2015 research cycle and in April 2020 (spring season) for the 2018 research cycle.
- Connected cracks were observed in parts of Section N7. Cores from these areas indicated that these cracks were full-depth and believed to have initiated from the bottom layer and propagated to the top, affecting the cracking performance of the surface layer.
- A spray-on rejuvenator is intended to slow the deterioration of surface distresses for pavements with sound structure. Thus, applying the Delta Mist spray-on rejuvenator to Section N7 when distresses had propagated from the bottom to the asphalt surface accelerated its failure.

Figure 4. Delta Mist Application on Section N7 in February 2020

Figure 5. Section N7 Milled and Inlaid in May 2020 (a) Milled Surface Showing Bottom-Up Cracking (b) Area of Severe Bottom-Up Cracks



Contact Nam Tran at nam.tran@auburn.edu for more information about this research.

Testing for Success

Did you know the NCAT laboratory offers specialty testing services? NCAT provides innovative and cost-effective testing to both the public and private sector. As an independent and experienced source of assessing materials and methods, we offer unbiased and comprehensive evaluations to keep your project on track. Our laboratory is AASHTO accredited for soil and aggregate testing and offers a wide variety of laboratory evaluations to suit your quality control and product development needs.

NCAT personnel are recognized leaders in pavement materials testing and are active participants in standards development and industry organizations. This multidisciplinary team of experienced engineers, scientists and technicians enables us to offer extensive testing and investigation capabilities to characterize materials, determine root causes of problems and evaluate performance.

The NCAT laboratory can perform AASHTO and ASTM tests for consensus aggregate properties, specific gravities, sieve analysis, LA Abrasion, micro-deval, clay lumps and friable particles, magnesium and sodium soundness and durability of aggregates. The laboratory is also equipped with the Aggregate Image Measurement System (AIMS) to provide shape, angularity and surface texture measurements. We collaborate with scientists across the Auburn University campus to provide many other analytical capabilities.

From polishing and British pendulum testing to texture and friction measurements, assessing the quality and durability of aggregates, friction treatments and pavement coating materials is essential in providing safe roads for the traveling public. NCAT's Three Wheel Polishing Device (TWPD) applies uniformly controlled conditioning in accordance with the new AASHTO Provisional Standard PP 104 Sample Preparation of Asphalt Mixtures for Dynamic Friction Testing. Along with ASTM E2157 Standard Test Method for Pavement Texture Properties Using the Circular Track Meter and ASTM E1911 Test

The TWPD rapidly simulates pavement polishing. The polished circle is then measured to evaluate friction characteristics.

Method for Measuring Surface Frictional Properties Using the Dynamic Friction Tester, NCAT engineers can assess the relative friction performance of any pavement surface. NCAT has provided polishing and testing on high friction surface aggregates for contractors and agencies in Alabama, Georgia, Florida, Maryland, Michigan and Washington.

Our services also extend beyond our laboratories; it is common for NCAT staff to take our expertise to the field and conduct specialized testing on-site after a material has been placed in the field.

Soils play an important role in the ultimate success of a paving project. We perform tests to analyze and classify soils using the most current industry standards and specifications to help determine if the materials for your project are being used to their full potential. Some common examples include: Atterberg Limits, proctor density, specific gravity and particle distribution.

No matter the size of the need, NCAT will help your project move forward. With our highly trained materials engineers and technicians, NCAT delivers the results you can trust.

Contact Jason Moore at jason.moore@auburn.edu for more information about this research.

Continuous Compaction Assessment Using a Density Profiling System

Construction quality assurance (QA) programs play a critical role for state highway agencies in ensuring that the materials and workmanship used on transportation projects is satisfactory and in reasonable conformance with their plans and specifications. Ideally, test results used in QA programs are available quickly enough to make adjustments in the production and/or construction operations to maintain the quality level desired.

Ground-penetrating radar (GPR) is a non-destructive testing technology that has been used for years to determine pavement layer thicknesses. Several studies have recently shown that density profiling systems (DPS) that use GPR technology can also be used to evaluate the in-place density of pavement as well as uniformity of the compaction operations, as shown in Figure 1.

A DPS unit, sometimes referred to as a rolling density meter, can identify the in-place relative density of pavements in near real-time by measuring the surface dielectric profile. Unlike coring and hand-held density gauge measurements taken from a few discrete locations, DPS units provide continuous measurements, resulting in nearly 100% coverage of the constructed layers.

However, there are still some limitations regarding this new technology. Field cores are typically used to calibrate the measured dielectric constant to actual pavement density, although a coreless calibration solution is currently being evaluated. In addition, more information on the precision and bias is needed, as well as training – not only for how to conduct the test but also to interpret and use the results for quality control and acceptance.

The coreless calibration process is conducted by correlating dielectric measurements with asphalt specimens fabricated at a range of air void contents using a Superpave gyratory compactor (Figure 2). The resulting calibration curve is later validated with a few field cores taken from a test section. The DPS can then be used to take measurements throughout the rest of the paving for that layer and produce thousands of data points that would be equivalent to cores taken continuously at a 6-inch spacing.

NCAT is currently providing support and engineering services to the Minnesota Department of Transportation on their ongoing project, Continuous Asphalt Mixture Compaction Assessment using the DPS. The study involves further development of the DPS testing protocols and specifications.

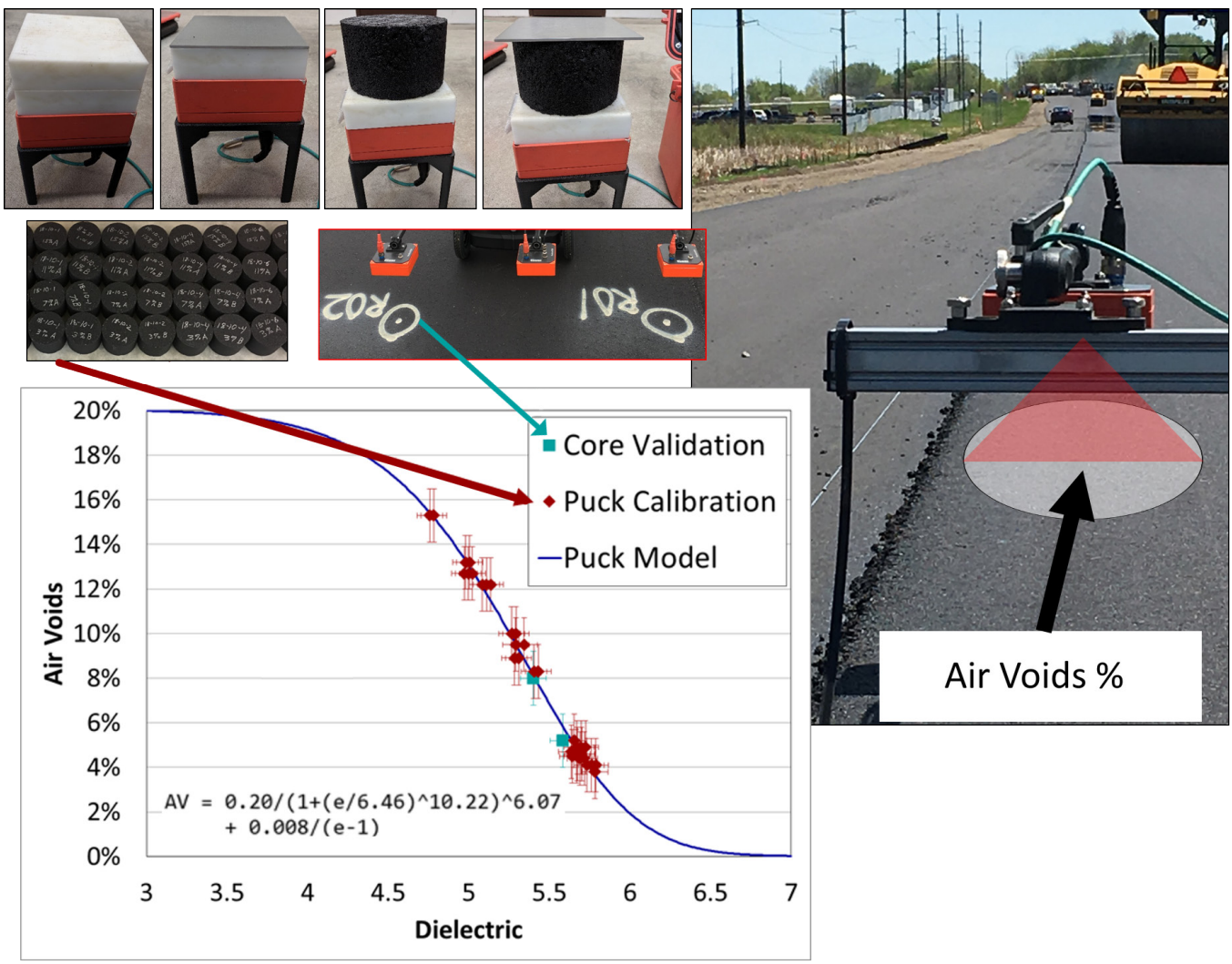
There are three primary tasks in the study. The first is to evaluate the effects of pavement layer thickness on DPS measurements, the second is to develop equipment and operator certification procedures and analysis methods and the third is to develop a precision and bias statement.

Most of the work will be performed at NCAT's main lab with field testing conducted during construction of the new test sections on the NCAT Test Track this summer. Results of this study are expected to be available by the end of 2021.

Contact Fabricio Leiva at leivafa@auburn.edu for more information about this research.

Figure 1. Density Profiling System

Figure 2. Density-Dielectric Correlation Process

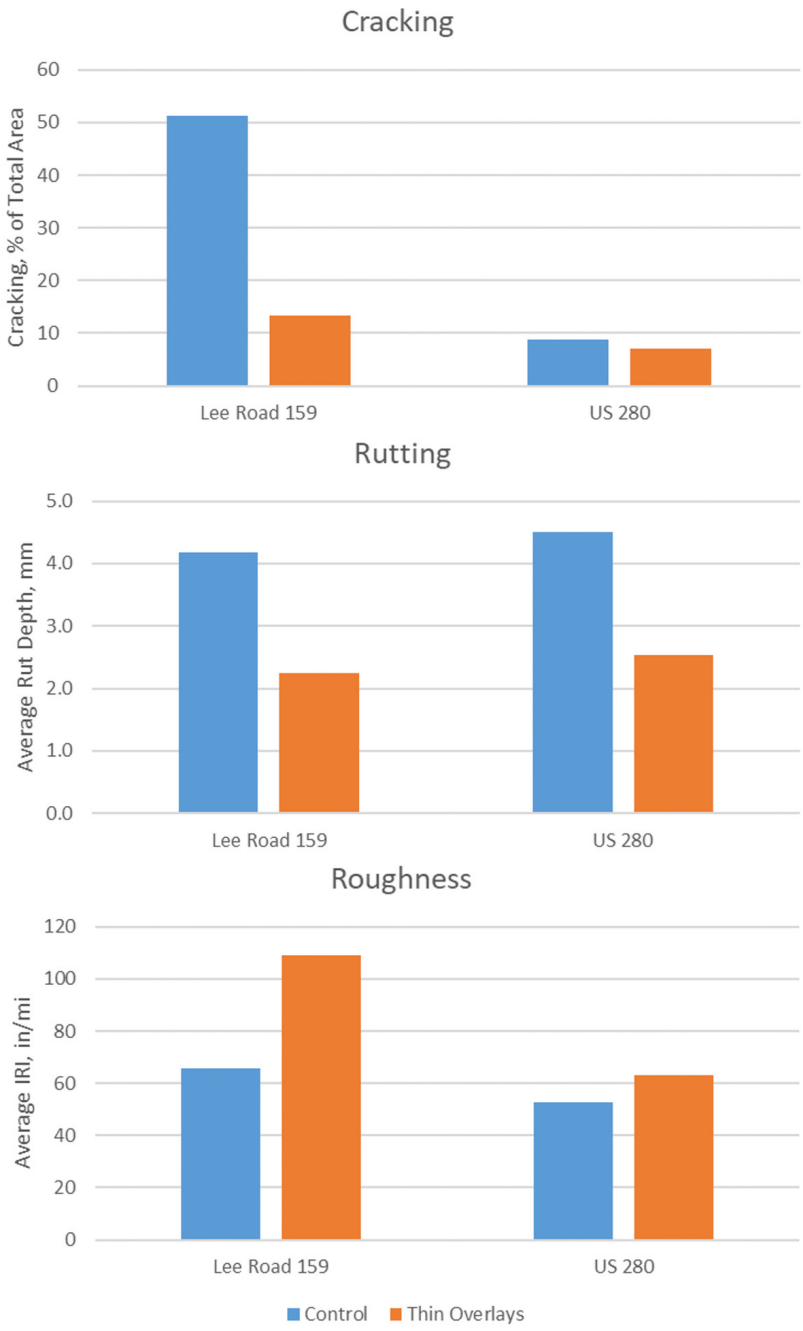


Thin Overlays for Pavement Preservation

Thin asphalt overlays are one of the most popular preservation treatments for asphalt and composite pavements. While the definition of what constitutes a "thin" overlay tends to vary among agencies, the term generally refers to surface mixes of 1.5 inches or less placed on a well prepared surface. Although thin overlays used for pavement preservation are not designed to provide additional strength to a pavement structure, this is a natural consequence in addition to other benefits including improving smoothness and friction, reducing tire-pavement noise and sealing the pavement from moisture at relatively low costs.

NCAT has been studying thin overlays as pavement preservation treatments since 2012, when the first test sections were placed on Lee Road 159 in Auburn, just a few miles away from NCAT's main facility. At the time, eight 100-ft test sections were placed as ¾" thin overlays to quantifying their life-extending benefits. The thin overlay test sections included all-virgin mixes with unmodified and modified binders, a mix with 50% reclaimed asphalt pavement (RAP), a mix with 5% shingles, a gap-graded bonded wearing course and thin overlays on other preservation treatments.

Figure 1. Performance Measurements for The Average of The Control and Thin Overlay Sections



Nearly nine years later, all of the thin overlay treatments have been proven to slow down the rate of deterioration and extend the overall life of the pavement. Cracking, which was the main distress observed on this roadway prior to the treatments, was reduced up to 65% compared to the untreated sections. Average rut depths are under 5 mm and roughness remains stable over time. Deflection data collected with the falling weight deflectometer shows that although these are not structural overlays, they definitely help maintain a good pavement in sound structural condition for a longer period compared to untreated pavements.

Based on the promising preliminary data obtained from the Lee Road 159 experiment, the scope of the project was expanded to study the effect of traffic and climate on treatment performance. Additional sections were built on U.S. Route 280 in Alabama, as well as on County State Aid Highway 8 (CSAH-8) and U.S. Highway 169 in Mille Lacs County, Minnesota. These sections have been in service since 2015 and 2016, respectively.

Findings from the Lee Road 159 sections were instrumental in designing the layout of the subsequent testing sites. For example, the mixtures containing 50% RAP and 5% recycled asphalt shingles (RAS) included in the original test sections provided reasonable performance, as cracking eventually exceeded 20% of the total area after approximately seven years of service. To improve performance while still benefiting from the use of recycled materials, the later experiments used an early balanced mix design approach and incorporated both RAP and RAS in smaller proportions. These BMD thin overlays have shown improved cracking performance even when subjected to higher traffic volumes.

Another example is the use of thin overlays as the wearing course over cold recycled asphalt bases. In 2012, one of the very successful test sections consisted of a thin overlay over a 97% RAP foamed asphalt recycled base. Following the results from this low traffic volume test section, additional sections were constructed on more trafficked roadways to see if similar performance could be achieved. To date, these sections have withstood the higher traffic loads with little surface distress.

As NCAT's pavement preservation research grew, other types of thin overlays were included in the study. Thin open-graded friction course overlays placed in high traffic test sections have maintained low levels of cracking, rutting and IRI. However, some functionalities associated with these mixtures (e.g. permeability and noise reduction) have decreased over the first five years of service. In addition, these sections were used to study different types of tack coats, all of which have provided adequate bond strength over time.

Using thin overlays in combination with other treatments such as chip seals or scrub seals can increase the benefits of proactive pavement preservation. As with stand-alone applications, improved performance and greater life-extending benefits can be expected when the existing pavement is in good to fair condition. Continuing data collection and long-term performance monitoring will allow us to better quantify the benefits from the thin overlay treatments as a function of existing condition, traffic and climate.

To date, all sections remain functional and exhibit less deterioration than the untreated surfaces, as seen in Figure 1. The higher roughness observed for the thin overlays are mainly related to the heavy braking conditions in the area where the thin overlays were placed.

While there are noticeable differences between treated and untreated sections, at this moment it is not possible to predict when the thin overlays will reach the end of their service life. The data collected in the upcoming years will be key to quantify the resulting life extension and assisting agencies in selecting the most cost-effective alternative to maintain their pavement networks.

Contact Adriana Vargas at adriana.vargas@auburn.edu for more information about this research.

Life Cycle Cost Analysis Residual Values

Highway agencies frequently use a life cycle cost analysis (LCCA) as a method to evaluate competing pavement design alternatives, primarily between asphalt and concrete pavements. An LCCA is a process that takes into consideration the expected costs over the life of each pavement alternative to identify which has the best long-term value. In addition to initial construction costs, an LCCA also considers future costs such as maintenance, rehabilitation and sometimes user costs, all of which are converted into present dollars (called net present value or cost). Any pavement value remaining at the end of the analysis period is called the residual value, which is discounted back to a present value as a credit or negative cost. A typical expenditure stream diagram for a project (excluding user costs for simplicity) is shown in Figure 1.

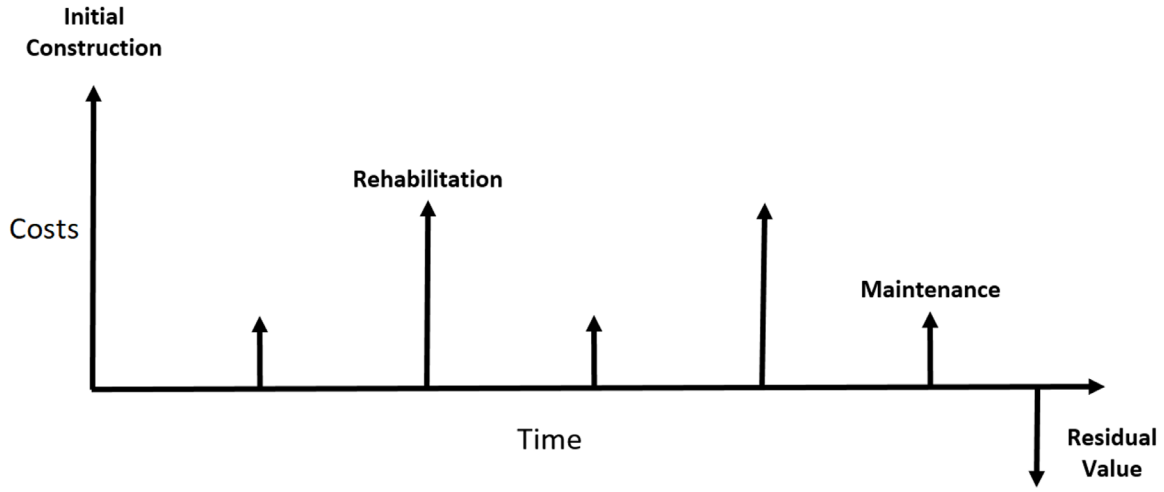
However, before we get into the mechanics of this issue, let's consider what actually happens to asphalt and concrete pavements when they reach terminal serviceability. Concrete pavements are either entirely removed and replaced with a new pavement, rubblized in-place and overlayed with asphalt, overlayed with concrete or overlayed with asphalt. The choice of these options typically considers their costs, the disruption to traffic for each option, the impacts to other infrastructure elements in the right of way due to roadway elevation change and the agency's historical success or failures with these options.

Another factor now being considered more often by some agencies is environmental impact. For asphalt pavements, rehabilitation options are most often a mill and fill resurfacing, a structural overlay if additional load carrying capacity is needed, and in rare cases when lower pavement layers are compromised, full-depth reclamation and recycling of the pavement structure.

While there are a number of inputs required when conducting an LCCA, this article focuses on determining the residual value of the pavement structure. A residual value for the pavement is determined at the end of the LCCA analysis period. Depending on the anticipated condition of the pavement alternative at that time, this value can either be the salvage value or the remaining service life (RSL) value.

If the pavement has no remaining service life at the end of the analysis period, a salvage value is typically assigned. This represents the potential value of reusing or recycling the materials that would be removed (reclaimed asphalt pavement, crushed concrete, etc.). History shows that asphalt is recycled much more than concrete. However, it's important to note that salvage values can be challenging to estimate since they depend on unknown supply and demand conditions anywhere from 35 to 60 years in the future. Consequently, they tend to be estimated on the low side, which makes them almost negligible when they are discounted back to a present day value.

Figure 1. LCCA Expenditure Stream Diagram



In cases where the expected service life of the pavement extends beyond the analysis period, a value for the remaining service life should be included in the LCCA. Historically, most published LCCA guidelines have only considered the remaining service life of the last rehabilitation that occurred prior to the end of the analysis period. This is determined as shown by the following equation and example:

$$\text{RSL Value} = \frac{\text{(Cost of Last Activity) x (RSL)}}{\text{(Expected Service Life of Last Activity)}}$$

For example, if the last activity or rehab occurs eight years prior to the end of the analysis period, and that rehab has an expected service life of 15 years and costs $200,000 per lane mile, the remaining service life would be seven years (15–8), and the RSL value would be:

$$\text{RSL Value} = \frac{\text{(\$200,000/lane mile) x (7 years)}}{\text{(15 years)}} = \$93{,}333.33/\text{lane mile}$$

This value would then be discounted back to time zero to determine its present value.

One shortcoming with this methodology is that the remaining service life value is only determined for the last rehabilitation activity and not the underlying layers. It is very rare to encounter a flexible pavement that requires complete reconstruction at the end of its service life. Unless the base or subgrade layers have failed, flexible pavements – composed of a combination of multiple asphalt layers, granular base and subgrade – are commonly rehabilitated multiple times by milling and replacing the upper asphalt layers or adding a structural asphalt overlay. In practice, this cycle of milling and resurfacing asphalt pavements typically continues indefinitely, so there is a significant real value for the lower pavement layers. For a more accurate LCCA, it is essential that the RSL value for all pavement layers be taken into consideration. This is especially true when an LCCA is being conducted to determine the economy of building a perpetual pavement.

A more comprehensive analysis is to determine the RSL value for the most recent resurfacing that occurred prior to the end of the analysis period and the RSL value for the underlying layers. Several alternative methods are described in NCAT Reports 19-03 and 20-05. One approach is to compare the historical structural capacity or structural number of asphalt pavements based on non-destructive testing such as the falling weight deflectometer (FWD) to determine how their structural capacity or structural number changes over time.

One recommended method of determining the RSL value of underlying layers is through the following equation:

$$\text{RSL value of Underlying Asphalt Structure} = C_{OD} \times \frac{SN_{EX}}{SN_{OD}}$$

In situations where the underlying granular base and/or subgrade of the asphalt alternative is different than the concrete alternative, the remaining service life value of those layers should also be determined. One option is to use non-destructive testing to determine how the structural characteristics of these layers typically change over time as described above.

If used properly, LCCAs can be an effective method for an agency to compare pavement alternatives. However, it is critical that all components be included in the analysis, including the appropriate residual value. If the life of the pavement alternative is expected to extend beyond the end of the analysis period, the remaining service life of both the last rehabilitation and the underlying layers must be included. In making pavement type decisions, it is also important to consider other factors that may be more challenging to include in an LCCA, especially factors that impact pavement types beyond the analysis period. An agency's history of what happens to asphalt and concrete pavements when they reach terminal serviceability is an important lesson to recall.

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

Asphalt Forum

NCAT invites comments and questions submitted to Christine Hall at christine@auburn.edu.

What experiences have other states had with balanced mix design? What were the challenges of BMD and performance testing, and how have you dealt with them? If using a bonus/penalty system for pay with volumetrics, how did you use the same system for performance testing?

-Zane Hartzog, Alabama DOT

We are still at the beginning stages of IDEAL-CT Testing and are looking into a balanced mix design approach for Colorado.

-Michael Stanford, Colorado DOT

What type of mix design programs are being used by contractors in your state? How does your state track or record binder source changes on a job mix formula (JMF)? Do you require a revision to the JMF or notification from the contractor when a source changes?

-Tony Collins, North Carolina DOT

What is the minimum and maximum lift thickness allowed in the specifications in terms of nominal maximum aggregate size (NMAS)? Virginia currently has a minimum two-and-a-half times and a maximum four times of NMAS. Are you satisfied with outcomes if you implement five or even six times?

-Sungho Kim, Virginia DOT

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

> How is density handled for portions of intersecting side streets that may be part of the scope of work for the mainline project? Are they included in density testing or are they exempted?
>
> -Greg Sholar, Florida DOT

NATHAN MORIAN, NEVADA DOT
In short, they are included, but with a different tolerance than would be considered for the mainline. We essentially consider them as requirements for acceptance testing but make allowances for non-typical placement, compaction, etc. Please see our 2014 NDOT Standard Specifications Section 402.03.03 Compaction for details (https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/engineering/design/standard-specifications-and-plans).

ERIC BIEHL, OHIO DOT
We would not do density checks if the contractor uses the same compaction effort as the mainline. Longer side streets could get density checks.

KEVIN SUITOR, OKLAHOMA DOT
Yes, all asphalt falls under density requirements.

CLIFF SELKINGHAUS, SOUTH CAROLINA DOT
If the tie ends to the intersections are less than 1500 feet in length, we do not require a gauge shot or cores. The contractor is required to maintain the same roller pattern and compact the same as their mainline section.

MATTHEW CHANDLER, TENNESSEE DOT
It would really depend on the scope of the side road. Theoretically, it should always be included in the potential random sample, but for very small tie ins, the inspector is unlikely to ever include those as possible locations. If there is a thousand or more feet of the side road included, the side road would almost certainly get tested for density.

HOWARD ANDERSON, UTAH DOT
We typically don't take cores for density in the intersections although we reserve the right to check density in those places. We expect to see the same effort given to density in those locations and our inspectors are aware that they need to observe the same compaction efforts.

SUNGHO KIM, VIRGINIA DOT
Yes, if it is within the main pull (on the mainline). It's hard to imagine density testing if it is within the side streets unless it is large enough.

SHAWN JACK, WEST VIRGINIA DOH
West Virginia Division of Highways tries to be reasonable whenever possible. For this situation, it is typically on a case-by-case basis. If there are large enough quantities of side streets/non-mainline work, then they may fall under a separate specification. Otherwise, in certain small cases, the method of acceptance for density testing is determined by the project engineer.

Specification Corner

ALABAMA DOT
ALDOT is in the process of adding a specification for an open-graded crack relief interlayer and adjusting our required tack rates for all surfaces.

COLORADO DOT
Colorado has no significant changes this year.

FLORIDA DOT
Florida will be expanding the upper density limit for the percent within limits (PWL) specification for normal production and also for the non-PWL small quantity production acceptance limit to encourage and not penalize higher density levels. We will also be requiring liquid anti-stripping agent as well as hydrated lime in all open graded friction course (OGFC) mixtures containing granite. If the granite is from Nova Scotia (which is used frequently in Florida) the hydrated lime dosage will increase from 1.0 to 1.5%. Georgia and Alabama granites will require 1.0% lime. This is based on FDOT funded research.

HAWAII DOT
Hawaii DOT will primarily be using stone matrix asphalt (SMA) and polymer-modified asphalt (PMA). We are also looking to do a pilot project on using recycled plastic in asphalt mixtures.

ILLINOIS DOT
IDOT has updated Illinois Flexibility Index Test (I-FIT) criteria for 2021 construction. The minimum short-term aged flexibility index (FI) criteria for SMA, 4.75 mm NMAS mixtures, and all other HMA are 16.0, 12.0 and 8.0, respectively. In 2021, long-term aged (LTA) I-FIT surface mixture specimens will be tested for informational purposes. In 2022, the LTA FI minimum criteria for surface SMA and HMA mixtures in production will be 10.0 and 4.0, respectively.

MASSACHUSETTS DOT
We have not made and are not planning on making any significant specification changes.

MINNESOTA DOT
We are moving forward with seven Superpave 5 pilot projects in 2021.

NORTH CAROLINA DOT
There are none planned at this time.

NEVADA DOT
We are currently in the middle of a rather significant revision of our cold in place recycling (CIR) specification. There are some minor materials changes, but most of the revision comes through mix design procedures (newly added from old recipe specifications), equipment requirements (to better control/limit added water as has been problematic on past projects) and density measures (to better achieve desired density following the field operations). Nearly all of these efforts have been undertaken to improve the consistency of our CIR projects. Previously, some projects would perform as expected, while others would exhibit early distresses with substantially reduced performance life.

SOUTH CAROLINA DOT
We have made changes to our Supplemental Specifications (SC-M-404 and SC-M-405) to require auto-Rice controllers for MSG (i.e. G_{mm}) determination in all mix design labs and in contractor-owned field labs starting in July 2021. We are currently working on revising our 2007 Standard Specifications.

UTAH DOT
We are constructing a highly modified asphalt pavement this summer as a test section on our port of entry truck ramp on I-80 near Wendover, Nevada. The ramp mix will be placed in a single 6-inch lift using a 50 gyration mix design with a low air void target of 1.5% and a UDOT PG 76-34 grade binder. The binder will have about 7.5% SBS polymer in it. The mix has been tested against rutting by running the Hamburg rut test using a higher water temperature of 54°C for twice the normal number of passes (40k). Because we have a rich mix and low void target for the pavement, the Hamburg test slab is compacted to 3.5% air voids. The mix is still passing our 10 mm maximum rut depth requirement. We hope this mix will perform well for high traffic, urban interstate pavements. Because it can be placed in one lift, we will reduce acceptance testing and construction time. The tack coat is also eliminated.

VIRGINIA DOT
Density bonus specification (5% bonus with core testing) is now applied to not only maintenance projects but also for construction projects.

WEST VIRGINIA DOH
For Standard Specification 410, Percent Within Limits Asphalt Paving, we are moving the secondary roads to a "PWL-lite" due to uncertainty and inconsistency in these secondary roads. Standard Specification 405 (Chip Seals) and Special Provision 407 (SAMI Seal) have changed gradations to allow standard AASHTO gradings of 8s, 9s, and 67s. This aggregate is more available and should hopefully lower prices on chip seal aggregates. We have recently introduced a project-level crack seal special provision. Previously, we only had a large, statewide crack seal special provision. A void reducing asphalt membrane (VRAM) was recently introduced to the committee, but has not yet passed.

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