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Technology News

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Message from the Director

I am inspired by NAPA's vision for net-zero carbon emissions for the asphalt industry. If you haven't heard about these aspirational goals to help halt climate change, I encourage you to visit asphaltpavement.org/climate.

Reaching these goals won't be easy; in fact, it's the opposite. Experts say we'll have to limit the rise in global average temperatures to under 2°C (3.6°F) above preindustrial levels—and ideally, under 1.5°C (2.7°F) by 2050. To achieve this, global energy-related CO₂ emissions will have to be reduced to 1.7 tons of CO_{2e} per person per year. To put this number into perspective, the U.S. carbon footprint related to energy is around 16 tons of CO_{2e} per capita, which means Americans will need to cut their emissions by almost 90%. That goal has been described as a "moonshot", relating it to the mission of my father's generation to put mankind on the moon and bring them home safely.

All sectors of the economy will have to make changes. According to the EPA, the transportation sector is the largest contributor to anthropogenic U.S. greenhouse gas (GHG) emissions, accounting for 29% of total GHG emissions. It's encouraging to see large and small companies step up to the plate and commit to net zero by 2050.

The pavements community has an important role to play. Stakeholders in the private and public sectors must work together and commit to slow global warming. NAPA's vision includes four goals for the industry to achieve by 2050—

1. Achieve net zero carbon emissions during asphalt production and construction.
2. Partner with customers to reduce emissions through pavement quality, durability, longevity, and efficiency standards.
3. Develop a net zero materials supply chain.
4. Reduce electrical intensities and transition to electricity from renewable energy providers.

Early strategies will include substantial reductions in energy used to produce asphalt paving mixtures, big increases to RAP contents, better utilization of locally available aggregate sources, cold recycling, and also building longer lasting pavements. To substantially reduce energy, contractors must reduce stockpile moisture contents, invest in other well-documented energy saving technologies at plants, and use WMA to reduce mix temperatures by 50°F or more for all mix production, not just some of the time.

Nationally, the average RAP content in new asphalt mixtures has plateaued over the last few years at about 21%. Although that's a percentage to be proud of, we can do more. For years, Japan and the Netherlands have been averaging at about 50%. In the U.S., we have the technical capability to achieve 50% RAP; NCAT has several case studies demonstrating that high RAP content mixes can be even more durable than traditional, moderate RAP content mixes or virgin mixtures. Surprisingly, there are several owner agencies, big and small, who still explicitly prohibit RAP in certain mixes. Implementing balanced mix design and quick and simple performance tests as part of quality assurance is a key to unlocking higher RAP contents and other innovative technologies that will assure that paving mixtures of tomorrow are durable, economical, and sustainable.



The net zero vision for asphalt pavements isn't just about emissions generated during construction, it's about their full life cycle, including the GHG generated by vehicles during the "use phase" as well as when the pavement requires rehabilitation. Accounting for emissions in all phases of a pavement's life will require a life cycle assessment. Over the next few years, growing efforts will develop the data associated with production of raw pavement materials, their transportation to the project, construction activities, estimating emissions from vehicles as we transition from internal combustion energy to battery or fuel cell powertrains, and finally, dealing with the pavement materials when rehabilitation is needed.

One thing is certain, we can't wait any longer to act. Although we don't have all of the steps worked out, we can and we must begin to make the changes we know can move us in the right direction for the sake of future generations.

A handwritten signature in black ink that reads "Randy C. West". The signature is fluid and cursive, with a distinct "R" and "W".

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

NCAT Research on Use of Recycled Plastics in Asphalt

Since China's prohibition of imported waste plastics in 2017, the U.S. plastics industry has been exploring new end-market applications for over 30 million tons of waste plastics generated every year. Potential uses include asphalt pavements, plastic composites, concrete, and wood composites. Marketing claims and media attention have stated that using waste plastics in asphalt can improve the performance of asphalt pavements while eliminating the plastic waste crisis. Although this idea appears to provide a win-win situation, it remains unknown whether the expected benefits can be fully achievable in practice.

In fact, the use of plastics in asphalt is a not new concept. The first reported use dates to the 1970s in Europe, where high-density polyethylene (HDPE) was used in Gussaspalt for pourable asphalt mixture applications. During the 1990s, considerable research efforts and field trials were devoted to two proprietary plastic modified asphalt products, namely Novophalt® and Polyphalt®. Novophalt® was demonstrated on projects in nearly 20 countries, but it did not gain acceptance into mainstream practice due to field performance issues and practical challenges with implementation. Polyphalt®, on the other hand, showed promising laboratory results but was not a commercial success due to economic and performance limitations.

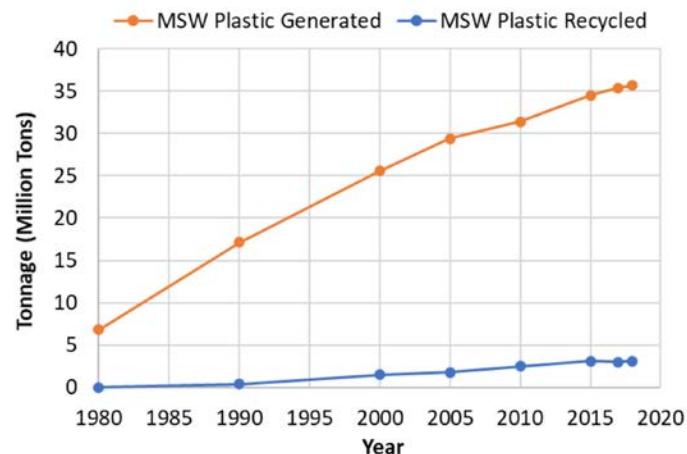
In 2019, the National Asphalt Pavement Association (NAPA) and Asphalt Institute (AI) established a joint task force on recycled plastics consisting of 15 members affiliated with various stakeholders in the asphalt industry. The task force contracted with NCAT to conduct a literature review and knowledge gap analysis on the use of recycled plastics in asphalt. Through this effort, NCAT researchers reviewed over 110 literature documents published between 1991 and 2020 and prepared an executive summary of the findings to present the 'knowns' and 'unknowns' for a wide range of topics related to the use of recycled plastics in asphalt. An annotated bibliography was also developed for each literature document to discuss its scope of work, findings, and recommendations. The executive summary and synthesis were published as a two-part NAPA document (IS-142) in October 2020. The information was recently expanded with 40

additional articles in the Phase I interim report of the ongoing National Cooperative Highway Research Program (NCHRP) Project 09-66.

The literature review found that approximately 35.7 million tons of waste plastics were generated in the U.S. in 2018, which accounted for 12.2% of municipal solid waste (MSW) generation. According to the Environmental Protection Agency (EPA), in 2017, polypropylene (PP) was the most common type of MWS plastic at 32.1% followed by polyethylene (PE) at 29.2%. Figure 1 presents the tonnage of total MWS plastics generated and recycled from 1980 to 2018. In 2015, recycling of MWS plastics reached approximately 3.1 million tons, a recycling rate of 9.0%. Currently, the vast majority of MSW plastics are combusted with energy recovery or landfilled.

One frequently asked question is, "How much recycled plastic can be used in asphalt?" The answer depends on which method is used—the wet process or the dry process. In the wet process, recycled plastics are added into the asphalt binder as polymer modifier or asphalt replacement, which requires mechanical mixing and, in some cases, additional compatibilizers to achieve and maintain a homogeneous modified binder blend. In the dry process, recycled plastic is added directly into the mixture as either aggregate replacement, mixture modifier, binder modifier, or any combination of these. Reported dosages for the wet process range from approximately 1 to 12% by weight

Figure 1. Tonnage of Generated and Recycled MSW Plastics from 1980 to 2020 (EPA)



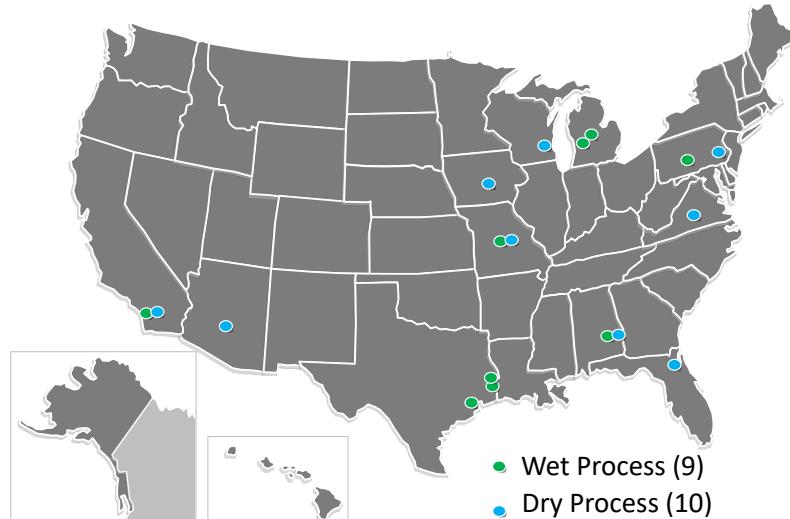
of asphalt binder, while for the dry process, the dosage varies from approximately 0.2 to 6% by weight of aggregate. Using the middle of these ranges indicates that the dry process can use up to 10 times more recycled plastics than the wet process.

Given that approximately 400 million tons of asphalt mixtures are produced each year in the U.S. and optimistically assuming 25% of these mixtures could be modified with recycled plastics via the dry process at an average dosage of 3% by weight of aggregate, approximately 2.8 million tons of recycled plastics could be consumed in asphalt pavements annually, which accounts for less than 10% of the total MSW plastics generated each year. This optimistic example highlights the fact that the possible use of recycled plastics in asphalt would not eliminate the growing amount of waste plastics being generated.

From the literature review, 19 field projects were identified that used asphalt mixtures containing recycled plastic in the U.S. since 2018, as shown in Figure 2. Among these projects, nine used the wet process of adding recycled plastics while the rest used the dry process. Most of these were commercial projects for parking lots and private roads. The two projects in Alabama represent test sections on the NCAT Test Track, which were constructed in September 2021 as part of the NCAT-MnROAD Additive Group (AG) experiment.

The AG experiment is a continuation of the successful partnership between NCAT and MnROAD to address national needs in asphalt research. The AG experiment includes three types of asphalt additives: recycled plastics, recycled tire rubber, and a synthetic fiber. A total of six structural test sections with a research focus on fatigue cracking were constructed on the NCAT Test Track, including two using mixtures containing recycled plastics— one using the wet process and the other using the dry process. The mixtures used the same post-consumer recycled plastic containing mostly linear low-density polyethylene that was supplied by a plastic recycler in Texas, but at distinctly different dosages for the wet process versus the dry process. The wet process also contained a reactive polymer to aid in compatibilization of the plastic in the binder.

Figure 2. Map of Recent Field Projects using RPM Mixtures in the U.S.



The test sections will be subjected to 10 million ESALs of accelerated traffic loading over a two-year period, and the structural response and pavement performance of those sections will be monitored. A comprehensive laboratory testing plan and modeling effort on the plant produced mixtures sampled during construction is also underway. A complementary experiment will be constructed this summer at MnROAD to evaluate resistance to reflection and thermal cracking. NCAT researchers and MnROAD engineers are working with several industry partners to evaluate different recycled plastic additives (and other types of additives) for potential use in construction of MnROAD test sections through a laboratory study. The NCAT-MnROAD AG experiment is believed to be the first field experiment in the world that evaluates the use of recycled plastics in asphalt based on accelerated pavement testing.



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A Comparison of CT_{Index} Devices

Imagine a scenario where a contractor works on a balanced mix design and finally gets that mix to pass an agency's IDEAL-CT criteria. Then, after submitting specimens to the agency for approval, the agency's results fail the mix design criteria. What happened? When the contractor and agency discuss the results, they realize both sets of specimens were tested with machines from different manufacturers.

Could using different devices be the reason for the discrepancy between the two labs? How can we ensure that different machines will provide equivalent results? A recent NCAT study could help resolve this situation, where six different devices were evaluated to assess how much they could affect the overall variability of IDEAL-CT results.

Variability in IDEAL-CT test results can come from many sources: operator, materials, specimen preparation, equipment differences, etc. Specimen preparation is known to have a large effect on IDEAL-CT results. For this study, careful attention to detail was given to making the specimens by using a single technician, using the same specimen preparation equipment and oven heating times, and by randomizing the specimens to be tested among the six devices.

When investigating differences in test results due to devices, analysis should include data from a variety of mixtures with results ranging from low to high. In this study, eight replicates from seven different mixtures were tested on each device by the same technician. Due to natural variability, results for each mixture will differ from device to device. Although replicates from a mix may be repeatable within the specific devices, there still may be differences when comparing results between devices. The concern is when one device consistently yields results that are higher or lower than another device. So how much of a difference can be tolerated?

Statistical equivalence is not a term used often in materials testing. This is the idea that results are considered equivalent when the differences between them are practically irrelevant. For example, if Sample A has an average CT_{Index} of 95 and Sample B has an average CT_{Index} of 93, is this two-unit difference large enough to be considered important given the test's variability? To establish a limit for acceptable difference, the analysis used the average within-lab variability (measured in COV%) from the 2018 NCAT Round Robin Study, where

the average within-lab COV was 18%. Therefore, when two devices can consistently produce mean results less than or equal to 18%, they should be considered equivalent.

Two key findings came from this study. First, some devices had average loading rates faster than the 50 ± 2 mm/min currently specified in ASTM D8225. All of the measured speeds from over 300 IDEAL-CT tests fell between 49 and 53 mm/min. Thus, although all the rates do not meet the standard's specified range of 48-52 mm/min, the devices are still operating within the maximum allowable 4 mm/min tolerance window. There was no discernable effect of speed on the final CT_{Index} results for each mix because the devices were operating similarly. Second, using the Two One-Sided Test (TOST) equivalence test, all but one of the devices were found to provide equivalent results. When the specific manufacturer was made aware of this issue, a flaw in the data collection system was found and the issue was corrected. Although there were differences up to 5 CT_{Index} units present in the final comparisons, these differences were not large enough to be considered relevant given the variability of the test. Thus, the study indicates that different devices can be trusted to yield equivalent results.

These findings do not mean that differences won't occur, and it's important to investigate large variances between comparison testing results. Following preparation and testing best practices will greatly reduce the chances of having a wide range between specimens from the same mix sample. It is highly recommended that when specimens are to be tested between two different devices, they should be prepared at the same time and under the same conditions to reduce variability between the split samples.



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Implementation Spotlight

Paving Thick Lifts for Deep Rapid Rebuilds

Research has shown that the minimum thickness of a plant-mix asphalt paving lift should be three times the nominal maximum aggregate size (NMAS) of the aggregate blend for fine-graded mixtures and four times the NMAS for coarse-graded mixtures. Lift thicknesses thinner than this are difficult to compact due to aggregate packing. However, there is little guidance on a maximum lift thickness.

Some pavement engineers suggest that it may not be possible to achieve the necessary density throughout lifts that exceed five times the NMAS. Contractors may share this concern because of the limited measurement depth of nondestructive density gauges. Despite this, some anecdotal success has been reported with thick lift paving. The South Carolina Department of Transportation (SCDOT) decided to evaluate the feasibility of paving thick lifts on the 2018 NCAT Pavement Test Track to consider the practice as an option for the rapid rebuild of failed truck lanes.

Because of their success with thick lift patching of the truck lane on I-85 in Greenville-Spartanburg, SCDOT suspected thick lifts could work for full depth reconstruction. The completely failed lane required full depth reconstruction accomplished using multiple lifts, each up to 4½". Their positive experience with the density and smoothness of those repairs encouraged SCDOT to experiment with even greater thicknesses on the NCAT Test Track. If proven to work, thick lift paving would be an alternative to cold recycling that could avoid pavement edge drop-offs with complete overnight reconstruction of relatively short (e.g., 1000- to 2000-foot) segments. Additionally, they could validate the use of thick lift paving as an option to create strong shoulders that could quickly be built for temporary traffic.

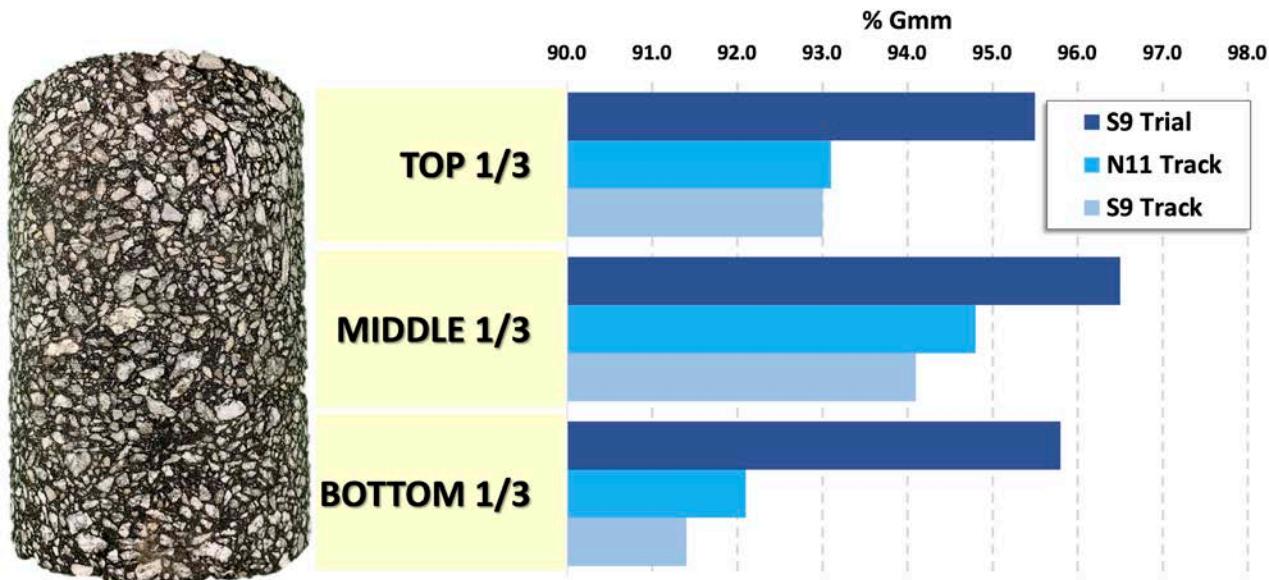


Installing instrumentation for thick lift paving in SCDOT's Test Track Section S9.

For thick lift paving to work, SCDOT needed to place a mix that could immediately support heavy traffic using a fine gradation for compactability and to avoid permeability issues. Based on the success of the I-85 rebuild, a 12.5 mm NMAS Type B intermediate special surface mix (typically placed at a thickness of only 2") containing 25% RAP and PG 64-22 virgin binder was specified for placement on the track. Design air voids were dropped to 2.5% and design gyrations were reduced from 100 to 75 to increase binder content, with the expectation that using RAP would increase stiffness and improve rut resistance. A chemical warm mix additive was used as a compaction aid.

In addition to evaluating the density profile of the full depth layer, the finished grade of the test lane after compaction needed to match the elevation of the inside lane remaining in place. A close centerline elevation match is necessary to maintain safety for the track's fleet operations, and the same concern exists with interstate paving. In conventional paving, a quarter inch of consolidation is expected for each inch of compacted mat, which means that to achieve an 8" compacted mat, the mat behind the screed should be 10". An off-track trial mix was built at approximately the same 8" compacted thickness required on the Track for Section S9 to successfully validate both the density profile and consolidation factor.

Figure 1. Density Measurements from Cores Cut into Three Slices on the 2018 NCAT Test Track



Another concern was smoothness of the compacted thick lift. Small screed changes (e.g., turning the screws slightly to adjust for thickness) produced large surface irregularities in the trial mix placement. For this reason, an additional practice was warranted to refine the process with actual paving on the track. Sections N10 and N11 needed full-depth reconstruction to support high performance thinlays, so the lower part of the asphalt pavement was built as a single 7" to 8" lift using a highly polymer modified (HiMA) binder. Although enough trucks were queued up to keep the paver moving continuously, the finished layer was very rough—approximately 400 inches per mile. However, the thinlays reduced roughness by more than half—around 150 inches per mile. Also, it should be noted that the Test Track has relatively short sections, which don't allow for typical paving adjustments like on a full paving shift. Sliced cores revealed that adequate density was achieved in the top, middle, and bottom of the compacted thick lift mat.

Based on the experience gained from the off-Track trial and the construction of Sections N10 and N11, SCDOT's Section S9 was constructed. High-speed instrumentation was installed to measure the pavement's structural response to loading. The mix was produced with Evotherm M1 warm mix asphalt at approximately 250°F and was placed directly on top of dense crushed aggregate base. Mat temperatures were recorded on the surface and with temperature probes throughout its depth during the compaction process. Analysis showed that the PaveCool software underestimated the cooling time of the thick lift and that the

temperature models should be adjusted for such conditions. No significant changes to compaction equipment or effort were necessary. Nondestructive surface densities showed good compaction during construction, which was later verified with cores. Average densities measured on sliced cores from all thick lift paving are shown in Figure 1. The thickness of the thick lift mat in Section S9 was approximately 8 3/8" after compaction with a roughness of approximately 350 inches per mile. Diamond grinding was later used to improve the roughness to just under 100 inches per mile at a final research thickness of approximately 8 1/8".

Performance of all three thick lift paving sections (N10, N11, and S9) on the NCAT Test Track has been outstanding through March 2022 with over 11 million equivalent single axle loads (ESALs) applied. Traffic will be continued throughout the current research cycle. No cracking has been measured on the HiMA sections (N10 and N11), and only a small amount of low severity cracking has been measured on the neat asphalt section (S9). No rutting or significant change in roughness has been noted on any of the three thick lift sections. Based on the success of this experiment, SCDOT adopted thick lift paving for select rapid rebuilds and overnight full depth patching.

For example, a badly deteriorated section of Highway 544 in Conway, South Carolina was repaved using thick lift paving in 2020. Paving was completed during an overnight lane closure, and lift thickness varied between 5" and 6". The project began in January when overnight temperatures were as low as the 30s and as high as the 50s.



Thick lift paving in 2020 on South Carolina Highway 544 at night with a dual lane closure.

Highway 544 was a five-lane curb and gutter roadway, which provided the ideal confinement for achieving good densities. Because it was possible to setup a dual lane closure, there was room for equipment to pull on and off the new mat in a manner that minimized surface irregularities. Full coverage diamond grinding (required for the first time ever by SC DOT) was utilized to reduce roughness from just under 100 inches per mile to the 30s. The contractor won paving awards from the South Carolina Asphalt Pavement Association and the International Grooving & Grinding Association (IGGA) for this project.

Another thick lift paving project was completed in April and May of 2021 on Holmestown Road in Horry County, South Carolina. Unlike SC Highway 544, Holmestown Road was not completed at night. Daytime paving temperatures were in the 70s and 80s. The road was not completely curb and gutter, so the paving was not entirely confined. Without space for a dual lane closure, there was no room for rollers to pull completely off the thick lift surface. Consequently, another lift was necessary to achieve a satisfactory ride.

SCDOT learned some useful lessons from these initial projects. Projects with confined lanes are preferred and paving in cool temperatures helps the mat cool faster so that traffic can be opened

to the roadway in a reasonable amount of time. Where possible, a dual lane closure allows trucks and the material transfer vehicle to stay out of the cut and provides a space for rollers to turn off the mat at the end of each pass. More trucks are required than for conventional paving, and it's essential to keep the paver moving at a steady speed. Diamond grinding or a thinlay is needed to provide the expected level of smoothness.

Other Test Track research partner states have expressed an interest in SC DOT's findings and field experience with thick lift paving, and some have plans to build trial projects in the 2022 paving season. For additional details on the SC DOT experiment, read the NCAT Phase VII (2018-2021) Test Track report.



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Airfield Asphalt Certification Program

Having qualified inspectors and technicians perform quality assurance measures is a critical component of asphalt paving. Although state DOTs have asphalt certification programs to meet this need, there haven't been nationwide or international programs to train and certify individuals for airfield pavements. Airfield specifications routinely reference ASTM D 3666: Responsibilities and Duties of the Agency, which requires that inspectors and technicians obtain proper certification. Airport project owners have commonly relied on state certification programs to meet this requirement, but there are important differences between paving for roadways and airport runways.

About a decade ago, Dr. Ray Brown of NCAT conceptualized one of the first military airfield paving certification programs, but there was no industry requirement or incentive to complete the training. In November 2020, an update to the asphalt paving sections of the Unified Facilities Guide Specification (UFGS) added the requirement for certified quality control project team members. Contractor submittals now require certifications for asphalt paving inspectors, asphalt laboratory technicians, and quality control managers. These certifications can be obtained through the newly formed Airfield Asphalt Certification Program (AACP) which is overseen by a management group of asphalt experts with experience in airfield paving who meet twice a year to guide the program.

AACP offers three certifications that align with the requirements in ASTM D 3666: Asphalt Pavement Inspector, Asphalt Laboratory Technician, and Quality Control Manager. This program is intended to increase the quality of construction on military airfields by providing the knowledge to the team members for successful airfield asphalt projects. Each course is offered quarterly or can be conducted onsite for companies or organizations outside of the regular schedule.

The Airfield Asphalt Laboratory Technician course is conducted at NCAT over three-and-a-half days of training that includes hands-on evaluations of QC tests and a written examination. Each attendee

must also meet prerequisites of three years of experience and/or education.

The Airfield Asphalt Pavement Inspector course is taught at the Asphalt Institute in Lexington, Kentucky. This course includes a written examination to gauge the knowledge of participants as well as minimum requirements of two years of experience or education.

The Airfield Asphalt Quality Control Manager course requires that the individual have one of the other two certifications (this prerequisite was waived for the first year of courses) and four years of education and/or experience. This course is conducted at NCAT and covers the UFGS specification in detail over two days with an exam held on the third day. Administration of the specification regarding lot sizes, QC testing, acceptance testing, and calculation of final pay are all included in the instruction and exam.

Since the first course was held in January 2021, 119 individuals have attended one or more of the courses. There are currently 62 certified QC managers, 36 paving inspectors, and 35 lab technicians made up of contractors, consultants, and government employees.

Upcoming course dates, prerequisite requirements, and course descriptions are available at airfieldasphaltpcert.com. All registrations are handled online, and there's also a searchable database that allows anyone to verify the status of an individual's certification on the website.



Contact Travis Walbeck at travis.walbeck@auburn.edu for more information about this research.

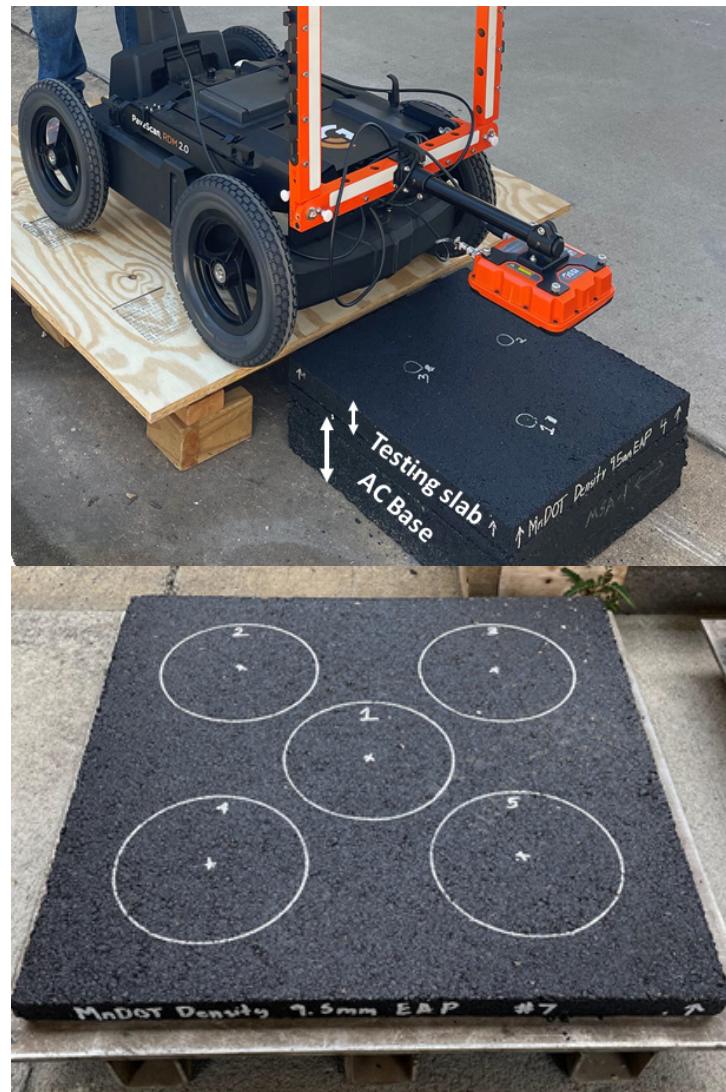
Density Profiling System Evaluation

Ground-penetrating radar (GPR) is a non-destructive testing technology that's been used for years to determine the thickness of pavement layers. Several recent studies have shown that GPR can also evaluate the in-place density of a pavement in a continuous manner, providing a better measure of the uniformity of compaction operations. However, research on these new density profiling systems (DPS). was needed to examine the effect of the thickness of the evaluated layer and the type of material underneath on the density results.

As part of a national pooled fund study (Pooled Fund TPF-5 [443]), NCAT evaluated the effect of thickness in the laboratory and evaluated the effect of the base material by placing and testing 2ft by 2ft compacted slabs on two asphalt pavements, one concrete pavement, and steel plates. Steel was used to have significant contrast with respect to typical pavement materials.

This evaluation also included field testing on several pavement sections built in 2021 as part of the NCAT Test Track's eighth cycle. Four slabs of varying thickness were compacted using two unmodified plant-produced asphalt mixtures with nominal aggregate maximum sizes (NMAS) of 9.5 mm and 19.0 mm. The 9.5 mm mixture was fine-graded and the 19.0 mm was coarse-graded. Target air voids of the slabs were set to 7.0% and five different locations of the slabs were selected to measure dielectric values with three replicates per location.

For the thin compacted slabs of both mixtures (0.9-inch for the 9.5 mm mixture, 1.8-inch for the 19.0 mm mixture), the average dielectric values were higher on steel than the other base materials. Thin surface layers over underlying asphalt layers provided the lowest readings. However, for thicker surface layers (1.8 inch for the 9.5 mm mixture and 3.0 inch for the 19.0 mm mixtures), the effect of the underlying layer type was not significant.



Slab test configuration and locations.

Field testing included six 100-ft sections built on the exit ramp of the NCAT Test Track. The sections had different base layers with a common hot mix surface lift approximately 1 inch thick. Five of the base layers were cold recycled mixtures using different additives: foamed asphalt, straight emulsion, soy based emulsion, a rejuvenator, and rejuvenated emulsion. The surface lift was a dense graded 9.5 mm NMAS mixture with a PG 67-22 asphalt binder and 20% RAP. The target air void content for the asphalt mixture was 6.0% or 94% of Gmm. Figure 1 shows an air voids map with several measured density profiles. High variability (poor uniformity) in air voids can be observed with values ranging from 0.0% to 15%.

Figure 1. Computed Air Voids from Density Profiles - Ramp Sections



Figure 2. Compaction Level from Density Profiles in Section N7



Table 1 shows the summary of the compaction level and percent within limits (PWL) analyses performed on each section. A typical range of 92 to 99% was used as limits for the analyses. Table 1 shows that most of the percent defective (PD) results were below the lower limit. The control section with the HMA lower layer had the highest PWL; the remaining sections with cold recycled asphalt lower layers had significantly lower PWL. Since the surface layer was thin (1.0 inch), the measured dielectric values were affected by the lower layer. Particularly, the presence of water in the underlying cold recycled layers will influence the dielectric values.

Table 2 shows a summary of the compaction level and percent within limits (PWL) analyses performed on sections built on the NCAT Test Track in 2021. Of these test sections, lower average compaction levels and lower PWL results were obtained for sections with thin lifts (≤ 1.5 inch). Sections with thicker asphalt surface layers not only had higher densities and PWL results, but also were more uniform. Figure 2 shows a compaction level map of Section N7 with the majority of the results obtained within a small range.

Table 1. Compaction Analysis - Ramp Sections

Material	Control	Foam	Emulsion	Soy Emulsion	Rejuvenator	Rejuvenated Emulsion
Mean %G_{mm}	93.6%	92.9%	93.5%	92.2%	92.7%	93.0%
Std. Dev.	1.64%	2.03%	2.13%	1.00%	2.35%	2.85%
Percent Below Lower Limit	15.0%	29.0%	24.8%	45.4%	34.9%	35.1%
Percent Above Upper Limit	0.30%	0.30%	0.10%	0.00%	1.60%	3.40%
Percent within limits (PWL)	84.7%	70.7%	75.1%	54.6%	63.5%	61.5%

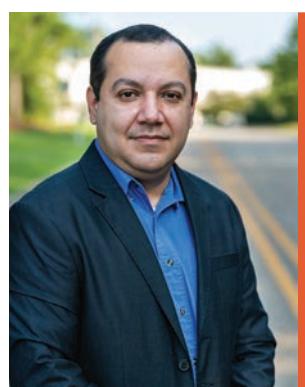
Table 2. Compaction Analysis - Test Track Sections

Test Track Section	S7A	S7B	S4	N8-1	N6	N8-2	N5	N7
Thickness, in	1.44	1.50	1.63	2.25	2.33	3.18	5.54	5.68
Mean %G_{mm}	91.2%	91.6%	94.8%	94.6%	97.2%	94.8%	95.3%	96.3%
Std. Dev.	2.96%	3.21%	1.33%	2.21%	1.15%	1.71%	1.50%	1.93%
PDL	59.1%	48.0%	2.4%	12.4%	0.0%	2.7%	0.2%	1.9%
PDU	0.4%	0.0%	0.0%	0.7%	6.8%	0.5%	0.7%	9.7%
PWL	40.5%	52.0%	97.6%	86.9%	93.2%	96.8%	99.1%	88.4%
%G_{mm} (cores)	92.4%	93.0%	92.7%	95.3%	94.4%	94.5%	N/A	96.1%

The following conclusions and recommendations are based on the results of this study:

- Thin layers (less than 2 inches) may be affected by the base materials with significantly different dielectric values compared to asphalt pavement.
- Thin asphalt layers over cold recycled layers are highly affected by the presence of water in the underlying layer, causing greater variability and the likelihood of poor density profiles. This issue is expected to occur for any underlying layer containing moisture.
- Measured air voids of thick asphalt layers tend to have lower variability and higher percent conforming.

- Dielectric and density evaluation of the existing surface prior to the construction of thin lifts is recommended to help explain the measured variability of such thin layers.



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In-Service Performance of Airport Asphalt Pavements Constructed with State Specifications

The Federal Aviation Administration (FAA) Reauthorization Act of 2018 initiated a requirement for the FAA to use highway materials specifications for pavements at non-primary airports (serving aircraft that do not exceed 60,000 pounds) if requested by the state. Due to significant differences in loading conditions between highways and airports, and since highway specifications were not developed for those conditions, the FAA asked NCAT to evaluate the performance of previously constructed airport asphalt pavements built using highway specifications compared to those constructed using traditional FAA specifications.

Information was collected and analyzed from 40 airport projects in five states to determine if there was a relationship between design, specifications, construction, and pavement performance. Twenty-one projects used FAA specifications and 19 used state highway specifications. A detailed review was also conducted of each specification, which focused on the requirements for aggregates, asphalt binder, mix design, quality control, acceptance, and construction.

Data from Pavement Condition Index (PCI) ratings were used to compare the performance of each project. Based on ASTM D5340 Standard Test Method for Airport Pavement Condition Index Surveys, PCI is a score (from 0 to 100) determined by a visual survey of pavement distresses. The data was obtained from pavement management reports provided by Applied Pavement Technologies Inc. The PCI ratings for each project were compiled and summarized based on the type of specification used (FAA vs. state). A plot of the data was then made of the PCI ratings by surface age for both FAA and state specifications, as shown in Figure 1.

PCI versus age for both types of specifications were fit with least-squares linear regression equations.

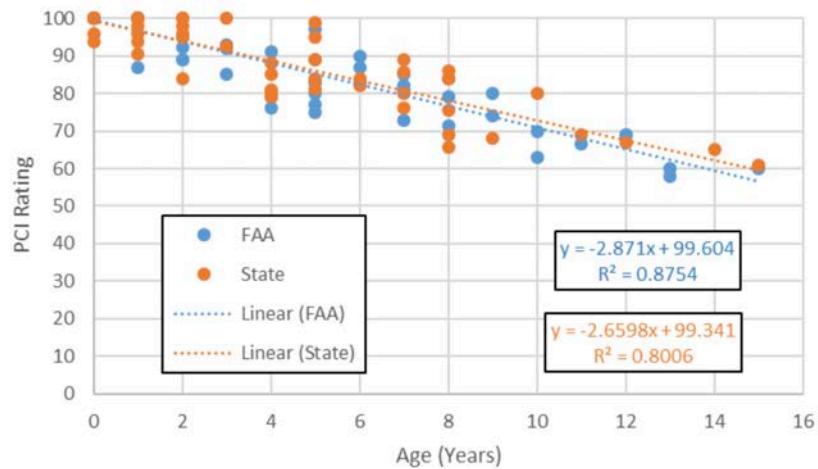
Both regressions had a good fit with coefficients of determination (R^2) of 0.87 and 0.80 for the FAA and the state data sets, respectively. An analysis of variance (ANOVA) of the data indicated that the type of specification used was not significant. The regression equations indicated a PCI rating of approximately 60 at year 14 for both types of specifications, which is considered to be "fair" condition based on the ASTM D5340 rating scale.

In order to determine if the type of specification impacted the types of distresses encountered, the percentage of distress deducts was summarized for each project. The distress deducts were characterized into three general categories:

- Load-related: alligator cracking, corrugation, rutting, and shoving
- Climate-related: block cracking, joint reflective cracking, longitudinal & transverse cracking, raveling, and weathering
- Other: bleeding, depression, jet-blast erosion, oil spillage, polished aggregate, patching & utility cut patch, slippage cracking, and swell distress

For both types of specifications, climate-related distresses were the predominant mode of distress on all projects, with longitudinal and transverse cracking the most prevalent.

Figure 1. PCI Rating vs. Age





Jason Moore (left) and Fabricio Leiva (right) inspect the main runway at the Columbus, GA airport.

With regard to the review of the specifications, while the mat density requirements were similar for both state and FAA specifications, the FAA has a strict method specification for joint construction plus a joint density requirement, whereas the majority of the state specifications examined did not. Although it would be expected that the FAA joint specification would have improved longitudinal joint performance, the available data did not show better performance for longitudinal or transverse cracking.

One important item to note is that several of the state specifications used on airport projects in this study were not true "highway" specifications. Of the five states evaluated, three had separate aviation specifications that were used for airport construction. These specifications were generally a blend of FAA and the state's highway specifications.

Based on this performance data analysis, no differences in pavement life were evident between airfield asphalt pavements constructed with FAA specifications and state specifications. This supports the continued use of state specifications for airfield asphalt pavements at non-primary airports serving aircraft that do not exceed 60,000

pounds—if requested by the state. However, additional guidance should be provided for airports using state specifications regarding the construction and acceptance of longitudinal joints.

Given the predominance of climate-related distresses on airfield asphalt pavements, further research is warranted on the selection of suitable mixture cracking and durability performance tests related to environmental distresses, and establishing criteria for the future use of the test (or tests) in FAA mix design and acceptance specifications.



Contact Jim
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more information
about this research.

Bowers joins NAPA's Carbon Emissions Task Force



Civil engineering assistant professor Benjamin Bowers is one of just three academics invited to join a one-year-old National Asphalt Pavement Association (NAPA) taskforce aimed at achieving zero net carbon emissions by 2050.

"It was an honor to be asked to serve on the task force that put together the National Asphalt Pavement Association's goals, tactics, and research and implementation gaps for achieving such an important objective," said Bowers, who specializes in sustainable and resilient pavements. "This really centers on a key component of my research program at Auburn and the National Center for Asphalt Technology (NCAT) – sustainability – and gives me an opportunity to work alongside and learn from industry leaders, allowing me to better understand the complexities of the industry and its challenges."

NAPA's four-part strategy for reducing carbon emissions involves achieving net-zero carbon emissions during asphalt production and construction, as well as reducing emissions through pavement quality, durability, longevity and efficiency standards. The taskforce is also intent on developing a net-zero materials supply chain and transitioning to renewable energy providers.

"Over 94% of pavements in the United States contain asphalt, so there is a serious opportunity to impact the carbon emissions of our built transportation network," Bowers said.

Bowers' research interests include sustainable design, infrastructure resilience, pavement materials, integration of reclaimed materials into pavement and cold recycling. He joined Auburn in 2018 and has more than 30 published peer-reviewed journals.

"This is the type of opportunity I dreamed of one day having in my career," Bowers said. "I just never thought it would happen so quickly."

For more about NAPA's net-zero carbon emissions goals, visit <https://www.asphaltpavement.org/climate>.

Asphalt Forum

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

We have Superpave5 pilot projects.

-Jerry Geib & John Garrity, Minnesota DOT

VDOT and the Virginia Asphalt Association have cooperatively developed and delivered our first BMD certificate training, which will be required of any technicians working on BMD starting with the 2023 season. This is a separate, stand-alone course focused solely on BMD. In the meantime, course materials are being developed and incorporated in our existing asphalt plant and mix design materials certification school courses (through the Virginia Education Center for Asphalt Technology, VECAT).

-Rob Crandol, Virginia DOT

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

Florida has a problem with a pavement distress known as "road worms" or "blisters." It has been documented since the early 1970's. There has been much speculation, but most believe it is caused by trapped moisture that vaporizes in hot weather and increases in volume between pavement layers, causing a blister to form on the surface. Debate exists of whether the moisture comes from the surface and penetrates into the pavement or comes from the lower granular layers and rises. A recent FDOT funded research project with ARA examined this issue and involved substantial field investigation of five roadways from various regions of Florida. Each roadway had road worm and control sections. The consensus for these five projects is that the moisture was coming from the top, and pavements with low in-place density and low interlayer bond strength had a propensity for exhibiting road worms.

-Greg Sholar, Florida DOT

BRIAN HILL, ILLINOIS DOT

IDOT has experience with blisters. In general, extended rain events before placement of low permeability (4.75mm or 9.5mm fine-graded) mixtures led to higher blister potential. IDOT requires the existing surface to be dry for at least 24 hours in the case of 4.75 mm mixtures for constructability. However, it can take much longer for moisture within the pavement structure to evaporate.

TONY D. COLLINS, NORTH CAROLINA DOT

We refer to road worms as blisters. Our findings are similar, trapped moisture and low bond strength. We have never done research on the issue to the same extent you have and find your research very interesting. We have been told by at least one expert that our mixes were "too tight" and this was causing moisture to be trapped coming up from the bottom.

How do other states determine when or if they can deviate from the AASHTO R 35 specified gyration level? In Montana, traffic over 3 million ESALs isn't all that common, so we decided several years ago to just use 75 gyration mixes. Obviously, we have numerous roads with less than 0.3 million ESALs, but we chose 75 for consistency. Now that states are using 30, 50, 60, etc. gyrations, I wonder: how do you get there? As an example, we have an out-of-state limestone quarry that wants to get into our market, but they claim they can't develop a 75 gyration design and want us to allow a 60 gyration design. This area of our state doesn't have good aggregate so a nearby limestone source would significantly reduce costs. This mix has performed in the supplier's local area. How do we adjust our contract language to take advantage? Do other states adjust gyration level by aggregate type? Is it strictly by traffic or have you conducted other research that resulted in a systemic decision to use a non-standard gyration level? Is it simply a project by project decision?

-Oak Metcalfe, Montana DOT

ZANE HARTZOG, ALABAMA DOT

ALDOT Uses $N_{\text{design}} = 60$ for all traffic levels. We arrived at that number based on the concept of locking point, detailed in section 3.2.1 of NCAT Report 19-08. Page 5 of FHWA Technical Brief HIF-11-031 should also be helpful (<https://www.fhwa.dot.gov/pavement/materials/pubs/hif11031/hif11031.pdf>).

MICHAEL STANFORD, COLORADO DOT

Colorado DOT does not adjust gyration levels for aggregate type. The gyrations are typically determined by traffic. 75 gyration mixes are our most common, along with a fair number of 100 gyration mixes. We also use an occasional 50 gyration mix for our thin lifts (3/8" NMAS).

GREG SHOLAR, FLORIDA DOT

At the onset of Superpave, FDOT used five traffic levels in accordance with AASHTO R35 (we followed Note 11 and divided the 3 to 30 million ESALs category into two categories split at the 10 million ESAL level). We then downgraded the 0.3 to 3 million ESALs from $N_{\text{design}} = 75$ gyrations to $N_{\text{design}} = 65$ gyrations in accordance with an NCAT report that we thought AASHTO would adopt but never did. FDOT also reduced N_{design} for 30 million and greater ESALs to 100 to get more binder in the mixtures. Very recently, FDOT further decided to use only three N_{design} levels as follows: less than 3 million ESALs = N_{design} of 65; 3 to 10 million ESALs = N_{design} of 75; greater than or equal to 10 million ESALs = N_{design} of 100.

BRIAN HILL, ILLINOIS DOT

IDOT back-calculated state-specific N_{design} levels for the entire state system. Mixture samples were collected and gyratory cylinders were compacted using Marshall designs that were known to perform well in specific traffic applications to identify the number of gyrations needed to reach 4.0% air voids. Traffic data was collected in conjunction with the mixture samples to tie the number of gyrations to 4.0% air voids to ESAL levels.

RICHARD BRADBURY, MAINE DOT

Maine DOT began specifying 65 gyrations for almost all projects several years ago. This decision was made primarily to streamline the design process for both DOT and industry by reducing the overall number of designs. We began deviating from the specified gyration levels in 2003 after noticing that some early Superpave projects were exhibiting distresses related to dry mixes. At that time, we expanded the use of 50 gyration mixes for many applications that should have been 75 gyrations according to the ESAL level. Over time, we observed that in most cases, producers were not using different aggregate blends; the only difference between 50 and 75 gyration mixes was a small change in design binder content. Consolidation to 65 gyrations seemed like a logical and low risk approach. Aggregate consensus properties are still specified based on ESALs, and we prevent rutting by specifying a stiffer binder grade.

TONY D. COLLINS, NORTH CAROLINA DOT

We have never considered different gyration levels based on aggregate quality, as we have relatively good aggregates across the state. Our deviation was based on findings of NCHRP 9-9, which showed mixes designed using the levels originally published did not achieve in-place voids of 4% after construction compaction and traffic densification. We were trying to add more effective binder to our mixes, which is why we added VMA limits of +0.5% for most mixes. Our mix specs are across the board and not project-by-project.

STACEY DIEFENDERFER, VTRC – VDOT

Virginia initially planned to adopt 75 gyrations for N_{design} for the highest traffic level and 65 gyrations for lower traffic levels at the beginning of Superpave implementation. However, the 75 gyration level was dropped to 65 gyrations prior to full adoption in 2000 due to experiences with coarse mixes and lower asphalt contents during trials constructed in 1999. Concerns with lower asphalt contents have continued, and several studies were performed at VTRC to look at increasing binder content (see VTRC 03-R15 and VTRC 11-R5 by Maupin and VTRC 15-R8 by Boriak et al. at VTRC.virginiadot.org). In 2014-2015, VDOT initiated an effort to evaluate the reduction in design gyrations, along with other adjustments to gradation and volumetric requirements as a means of improving mixture performance. Several field trials were constructed in 2015 that included 50-gyration mixtures for evaluation and the in-service performance of those mixtures is still being monitored. During production and construction, evaluation indicated that overall, there were only slight changes in asphalt content; however, the 50-gyration mixtures showed improved density and permeability (VTRC 21-R11 by McGhee & Smith). Currently, all dense-graded mixtures are designed at 50 gyrations regardless of traffic level.

At what temperature should the Hamburg wheel tracking test be conducted? MN started at 50°C but we have moved to 46°C.

-John Garrity, Minnesota DOT

MICHAEL STANFORD, COLORADO DOT

Colorado DOT test temperatures are determined for the SHRP high temp PG as follows: PG 58: 45°C; PG 64: 50°C; PG 70: 55°C; PG 76: 55°C.

GREG SHOLAR, FLORIDA DOT

FDOT conducts the test at 50°C.

BRIAN HILL, ILLINOIS DOT

IDOT uses the Texas test temperature of 50°C and varies the number of passes based on the PG high temperature grade. IDOT adjusted the minimum number of passes for PG 58 and PG 64 high temperature grades during initial implementation.

Specification Corner

ALABAMA DOT

Our 2022 Standard Specifications have been released, and many previous special provisions are now standard specification. Smoothness requirements and pay factors have been updated and can be found on page 222 (<https://www.dot.state.al.us/publications/Construction/pdf/Specifications/2022/SpecBookComplete.pdf>).

We plan to increase laydown rates for OGFC to 90-110 lb/sy above asphalt layers and 90-135 lb/sy above concrete layers. We are also discussing increasing the maximum laydown rate for asphalt binder layers. The current maximum is 350 lb/sy.

COLORADO DOT

No significant specification changes this past year.

FLORIDA DOT

Significant specification changes for 2022 include:

1. Increasing the tack rates to 0.06 gal/sy emulsion rate for paving over a new layer and 0.09 gal/sy emulsion rate for paving over a milled surface, old pavement (not a new layer), and concrete pavement.

2. Limiting the maximum temperature of asphalt mix containing polymer modified binder to 355°F to avoid degradation to the SBS polymer.

MINNESOTA DOT

MnDOT has a new working special provision for a Void Reducing Asphalt Membrane (VRAM).

NORTH CAROLINA DOT

No significant changes at this time.

VIRGINIA DOT

We are continuing our BMD development and implementation plan(s). In 2022 and 2023, we are asking each of our districts to have at least one contract be solely BMD mixes (currently only surface 9.5 and 12.5mm mixes).

Research continues on two key areas:

1. The relationship between reheated (VDOT) and non-reheated (industry) split samples taken during production for QA/IA.
2. The impact(s) of critical aging, and what that tells us about the ability to meet the agency's performance needs while allowing innovations with recycled materials.



VRAM application photo courtesy of Todd Thomas.



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