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Balanced Mix Design Field Trial Projects in Alabama

Final Report

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The Alabama Department of Transportation (ALDOT) is advancing Balanced Mix Design (BMD) to improve the durability, reliability, and cost-effectiveness of asphalt pavements. To support implementation, a field validation project was conducted on State Route 55 in Covington County, Alabama, using six asphalt mixtures designed to meet target thresholds for the Cracking Tolerance Index (CT_{Index}) and High-Temperature Indirect Tensile Strength (*HT-ITS*). Laboratory evaluation included the IDEAL-CT, HT-IDT, and Hamburg Wheel Tracking Test (HWTT) on lab-mixed/lab-compacted (LMLC), hot-compacted plant-mixed/lab-compacted (H-PMLC), and reheated plant-mixed/lab-compacted (RH-PMLC) specimens.

Laboratory results confirmed that specimen types significantly affect measured performance: reheating reduced CT_{Index} values while increasing HT-ITS due to aging effects. Despite these shifts, the relative ranking of mixtures was preserved, suggesting that specimen type specific thresholds may be warranted. Correlation analyses showed weak associations between volumetric properties and performance indices, underscoring the need for direct performance testing in BMD.

One year of field monitoring indicated no cracking and no systematic differences in roughness or macrotexture, but rutting trends aligned with laboratory predictions. Strong correlations were observed between field rutting and HT-ITS (R^2 up to 92.6%), while HWTT exhibited moderate correlations. These findings provide early validation of ALDOT's BMD framework and support refinement of performance thresholds to enable future implementation consideration.

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1. INTRODUCTION

Asphalt mixtures are essential for the durability, safety, and cost-effectiveness of Alabama's transportation infrastructure. These mixtures must withstand diverse climatic conditions, from hot and humid summers to occasional freezing temperatures, while accommodating varying traffic loads that challenge pavement performance.

Historically, the design of asphalt mixtures in the United States, including Alabama, has depended on volumetric methods such as the Marshall and Superpave systems. These methods aim to optimize aggregate gradation and binder content based on volumetric parameters, which include air voids (V_a), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA) (AASHTO, 2023, 2024; Asphalt Institute, 2014). While the Strategic Highway Research Program (SHRP) aimed to incorporate performance tests into the Superpave mix design system, these tests were found to be impractical for routine use. As a result, volumetric properties have remained the primary design criteria for decades. While the Superpave volumetric mix design system enhances resistance to rutting, it does not ensure adequate resistance to cracking, particularly for mixtures containing high levels of reclaimed asphalt pavement (RAP) or recycled asphalt shingles (RAS). Additionally, the system does not fully account for the benefits of additives like polymers, warm mix asphalt (WMA), or rejuvenators (Hajj et al., 2025; Yin & West, 2021).

Acknowledging the limitations of traditional methods, the Balanced Mix Design (BMD) approach was developed to incorporate performance tests on conditioned specimens. This method can be followed to design mixtures that resist various types of pavement distress, such as rutting, cracking, and moisture damage. BMD also accounts for important factors such as mixture aging, traffic, climate, and pavement structure (Yin & West, 2021).

Through the BMD approach, optimal asphalt mix designs can be developed to ensure resistance to both rutting and cracking. Several performance tests have been evaluated, including the Hamburg Wheel-Tracking Test (HWTT), which assesses rutting and moisture susceptibility; the Indirect Tensile Asphalt Cracking Test (IDEAL-CT), which evaluates intermediate temperature cracking resistance; and the High Temperature Indirect Tension (HT-IDT) test, which serves as a simpler alternative method for assessing rutting. The BMD approach enhances pavement durability and allows for a higher percentage of recycled materials, reducing the dependence on virgin materials (Yin & West, 2021).

Since 2022, the Alabama Department of Transportation (ALDOT) has begun incorporating elements of BMD into its practices. This includes the use of HWTT for high-traffic Superpave mixes, specifically those with 10 million or more equivalent single axle loads (ESALs), as well as Stone Matrix Asphalt (SMA) designs. ALDOT has also utilized the IDEAL-CT and HT-IDT tests to benchmark mixture resistance to cracking and rutting.

Other BMD initiatives in Alabama include special provisions for local roads and field trials utilizing modified and recycled mixtures. Supported by the Federal Highway Administration (FHWA) through the Accelerated Implementation and Deployment of Pavement Technologies program, a field validation study on BMD was conducted on State Route 55 (SR-55), which is the focus of this report. This rural highway is projected to accommodate approximately 3.55 million ESALs over the next 20 years.

2. PROJECT OBJECTIVES AND SCOPE

The primary objective of this study was to validate the performance thresholds for the IDEAL-CT and HT-IDT tests in the specific traffic and climate conditions of Alabama. This validation was essential for refining ALDOT's BMD special provisions, ensuring that laboratory test results are consistent with real-world performance.

The study involved selecting target BMD performance thresholds for six asphalt mixtures to be constructed on SR-55. The six mixtures were designed by varying their components to meet the chosen BMD performance targets. The mixtures were then produced and placed in six test sections for field evaluation. During the laboratory design phase, the contractor measured the volumetric and mechanical properties of the mixtures, which were then verified by ALDOT. During production, the plant-produced mixtures were also tested for volumetric and mechanical properties in both hot-compacted and reheated conditions to provide a comprehensive understanding of their performance.

Additionally, pavement surface conditions were surveyed at several stages: before construction, after milling, immediately after paving, and approximately one year post-construction. High-speed pavement condition survey vehicles were utilized for this data collection, providing detailed roadway condition data over time.

The laboratory test results were then compared with field performance data—specifically, cracking, rutting, and ride quality—collected annually. These findings will be used to refine future specifications and assist ALDOT in building and maintaining safer, more reliable roadways that deliver significant economic and community benefits.

3. METHODOLOGY

3.1 Experimental Plan

The experimental plan for this study is shown in Figure 1 and organized into five tasks, as follows:

1. Selection of target BMD performance criteria;
2. Development of asphalt mixtures that satisfy the selected BMD performance thresholds;
3. Construction of field test sections and testing of plant-produced mixtures;
4. Monitoring of in-service pavement performance; and
5. Comparison of laboratory test results with field performance data to validate the BMD performance thresholds and refine ALDOT's BMD special provisions. Performance monitoring will continue annually to capture short-term and long-term field performance trends.

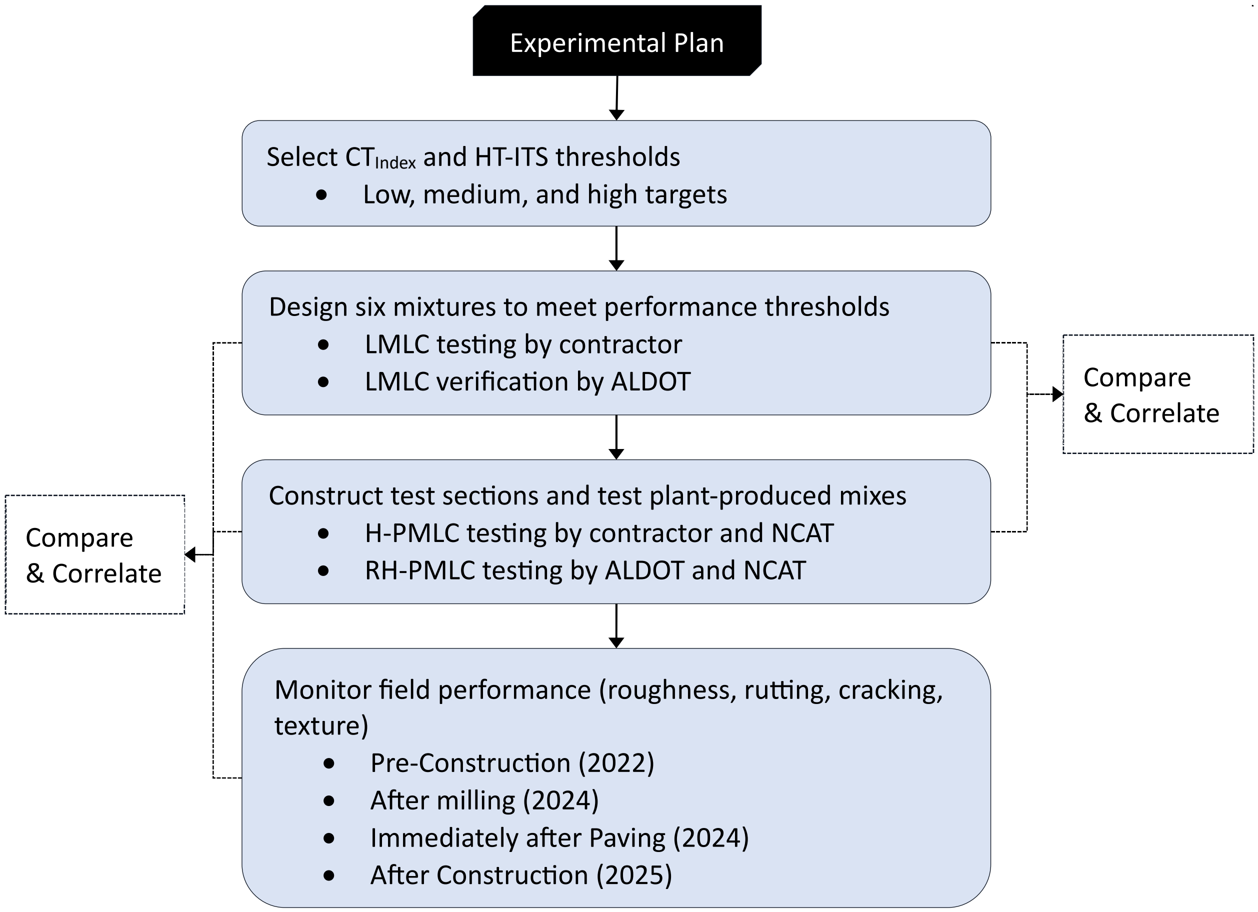


Figure 1 Experimental Plan.

Note: CT_{Index} = Cracking Tolerance Index, *HT-ITS* = High-Temperature Indirect Tensile Strength, LMLC = Lab-Mixed, Lab-Compacted, H-PMLC = Hot-Compacted Plant-Mixed, Lab-Compacted, RH-PMLC = Reheated Plant-Mixed, Lab-Compacted.

3.2 Selecting Target BMD Performance Criteria

Target BMD thresholds for the Cracking Tolerance Index (CT_{Index}) and High-Temperature Indirect Tensile Strength (*HT-ITS*) were established through consensus based on findings from a previous ALDOT-sponsored benchmarking study (Tran et al., 2023). The benchmarking study was conducted using a dataset of 212 asphalt mix designs approved in Alabama between 2020 and 2022 with PG 67-22 or PG 76-22 virgin binders. The dataset consisted of volumetric mix designs and IDEAL-CT and HT-IDT performance test results. Asphalt contents ranged from 4.4% to 6.8% (mean = 5.6%). RAP contents were limited to 20% or less, with an average of 18.5%. Notably, 86% of mixtures contained exactly 20% RAP, reflecting typical practice in Alabama.

The distribution of the CT_{Index} (Figure 2) is right-skewed, with values ranging from 6.3 to 342.9 and an average of 60.8. According to ALDOT's BMD specifications for local roads, a minimum CT_{Index} of 50 is required (NAPA, n.d.). In the benchmarking study dataset, 55.2% of the mixtures fell below this minimum requirement, while the remaining 44.8% met or exceeded the benchmark (Tran et al., 2023).

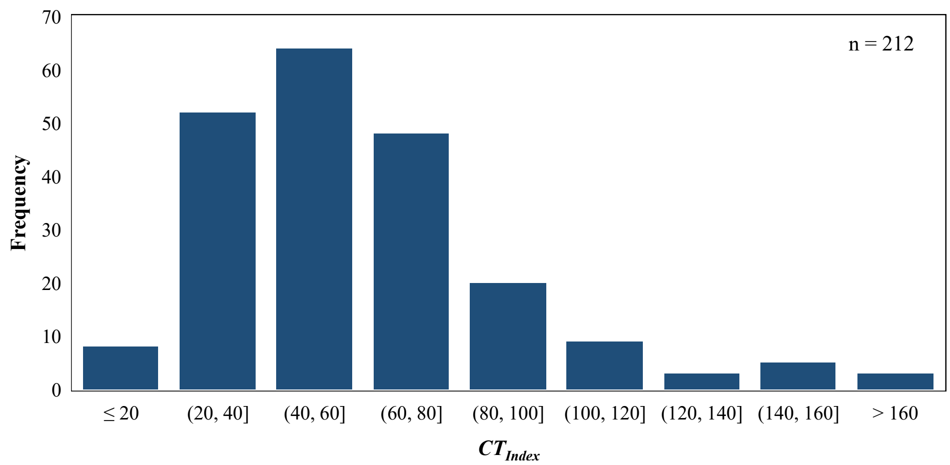


Figure 2 CT_{Index} Histogram (Tran et al., 2023).

The HT-ITS distribution (Figure 3) was also right-skewed, with values ranging from 4.4 psi to 130.0 psi. The mean and median values were 45.3 psi and 43.1 psi, respectively, with 81% of mixtures between 20 and 60 psi. ALDOT's BMD specification for local roads require a minimum HT-IDT criterion of 17 psi (NAPA, n.d.). Most of the mixtures tested in the benchmarking study met or exceeded the required rutting resistance in the specification.

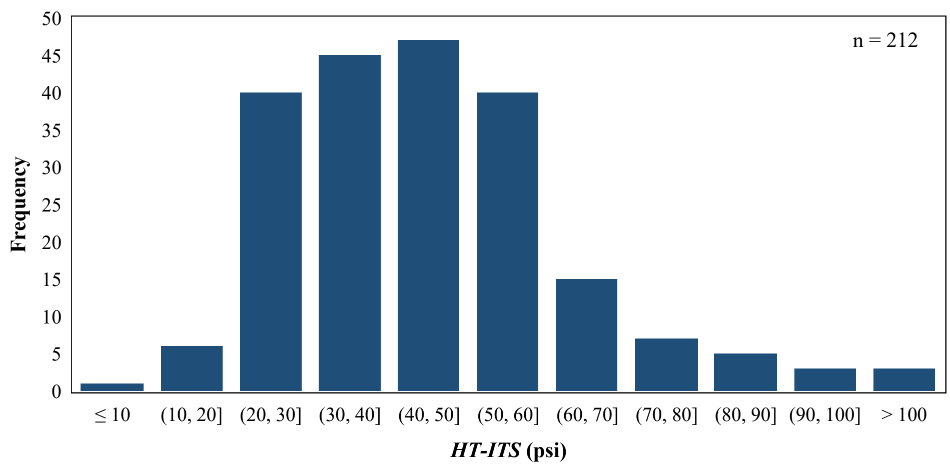


Figure 3 *HI-ITS* Histogram (Tran et al., 2023).

A consensus was reached during a meeting held on June 14, 2022, which included representatives from ALDOT, the Alabama Asphalt Pavement Association, contractors, and NCAT. The threshold values were categorized as low, medium, or high, as shown in Table 1. In addition, the volumetric requirements were intentionally relaxed to allow designers to focus on achieving the selected BMD performance thresholds. The volumetric requirements are summarized in Table 2. A copy of the project-specific special provisions and other requirements can be found in Appendix A.

After selecting the thresholds, special provisions were drafted and included in the project bidding documents. The project was awarded on December 8, 2023.

Table 1 Target BMD Performance Thresholds for Six Test Sections

Test Section	Target CT_{Index} at 25°C	Target HT-IDT Strength at 50°C
1	55-77 Med	14-18 psi Low
2	83-117 High	14-18 psi Low
3	27-39 Low	19-27 psi Med
4	83-117 High	19-27 psi Med
5	27-39 Low	28-38 psi High
6	55-77 Med	28-38 psi High

Table 2 Requirements for Volumetric Properties

Criteria	Requirement
Design Air Voids	1.5% - 6.5%
RAP Content	35% maximum by weight of aggregate
RAS Content	No limit, provided RAP and RAS together do not exceed 35%
Passing Maximum Aggregate Size Sieve (MAS) (%)	100% Minimum
Passing Nominal Maximum Aggregate Size (NMAS) (%)	90% Minimum and 100% Maximum

3.3 Designing Asphalt Mixtures to Meet Target BMD Performance Criteria

After the contract award, the contractor immediately began designing mixtures for the six test sections. Mix designs were first tested by the contractor and subsequently verified by ALDOT using contractor-prepared specimens. Final designs were approved in March 2024.

Key mix design properties from the approved Job Mix Formulas (JMFs) are presented in Table 3. Except for Section 6, which used a PG 76-22 SBS polymer-modified binder, all sections incorporated PG 67-22, Alabama's standard binder grade. Total binder content ranged from 5.3% to 5.8%, while RAP content varied between 10% and 35%. Although allowed under the special specifications, no RAS was included.

Table 3 JMF Mix Design and Volumetric Properties across Experimental Mixtures

Mix Properties	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
Binder Type	PG 67-22	PG 67-22	PG 67-22	PG 67-22	PG 67-22	PG76-22
Total Binder (%)	5.3	5.6	5.4	5.8	5.4	5.8
Virgin Binder (%)	4.80	4.85	4.40	4.30	3.65	4.55
RAP Content (%)	10.0	15.0	20.0	30.0	35.0	25.0
Air Voids (%)	4.6	3.4	5.5	2.8	3.8	3.8
VMA (%)	15.7	15.2	17.2	15.2	15.3	15.6
VFA (%)	70.7	77.6	68.0	81.6	75.2	75.6
D/P_{be}	0.80	0.72	0.98	0.82	1.10	0.99

Aggregate gradations are shown in Table 4. All mixtures were designed as 9.5 mm NMAS, with the #8 sieve identified as the Primary Control Sieve (PCS). Mixtures in Sections 1, 2, and 4 were coarse-graded, whereas Sections 3, 5, and 6 were fine-graded.

Table 4 JMF Aggregate Gradations

Sieve	Percent Passing for Different Sections					
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
3/4"	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	99.0	99.0	100.0	99.0	99.0	100.0
3/8"	90.0	90.0	97.0	90.0	96.0	97.0
#4	64.0	63.0	75.0	62.0	72.0	72.0
#8	44.0	42.0	53.0	42.0	48.0	49.0
#16	36.0	34.0	44.0	35.0	39.0	38.0
#30	29.0	27.0	35.0	28.0	30.0	30.0
#50	13.0	13.0	17.0	14.0	16.0	16.0
#100	6.0	6.0	8.0	7.0	9.0	8.0
#200	4.2	4.0	5.3	4.7	5.9	5.7

To limit variability between laboratory designs and plant-produced mixtures, production tolerances were specified in Table 5. These tolerances were used to verify that the produced mixtures conformed to design intent. Detailed comparisons of design and production properties using Quality Control (QC) data are included in Appendix B.

Table 5 Production Tolerances for Deviation from Mix Design

Mix Design Properties		Acceptable Tolerance
Asphalt Content		±0.30%
Air Voids Content		±0.50%
Percent Passing of	#8 or larger Sieves	± 7%
	#16 to #100 Sieves	± 4%
	# 200 Sieve	± 2%

3.4 Constructing Test Sections and Testing Plant-Produced Mixtures

Six test sections, each approximately 1,000 ft long, were constructed on an approximately 6000 ft long segment of State Route 55 in Covington County, between River Falls and Red Level. This site was selected for its uniform geometry and consistent traffic conditions, including a straight alignment, level grade, and absence of major intersections, bridges, or culverts. Section locations, GPS coordinates, and milepost details are summarized in Table 6, and the layout is shown in Figure 4.

Table 6 Section Location Details

Section	GPS	Station	MP
Begin Sec 1	31.40009619, -86.58298174	238+18.24	35.86
End Sec 1/Begin Sec 2	31.40121251, -86.58600282	248+18.24	
End Sec 2/Begin Sec 3	31.40236838, -86.58914785	258+18.24	
End Sec 3/Begin Sec 4	31.40345752, -86.59243102	268+18.24	
End Sec 4/Begin Sec 5	31.40430053, -86.59504789	278+18.24	
End Sec 5/Begin Sec 6	31.40515002, -86.59769993	288+18.24	
End Sec 6	31.40614646, -86.60041368	298+18.24	37.00

Figure 4 Layout of Test Sections.

During construction, samples of plant mix were taken to prepare two specimen types, as follows:

- Hot-Compacted Plant-Mixed, Lab-Compacted (H-PMLC): Collected from the plant during production, reduced in size, and compacted with minimal delay to limit aging, following NAPA IS-145 guidelines.
- Reheated Plant-Mixed, Lab-Compacted (RH-PMLC): Bulk plant mixtures cooled, transported, and later reheated prior to compaction per NAPA IS-145.

The specimens were randomized and tested according to the laboratory testing plan outlined in Table 7. The results from these tests can be compared with those of lab-mixed, lab-compacted (LMLC) specimens, which were prepared using representative materials from the asphalt plant during the mix design phase. Loose mixtures were subjected to short-term aging at 135°C (275°F) for 2 hours, as specified in AASHTO R30-22, before compaction. Additionally, IDEAL-CT and HT-IDT tests were conducted during both the design and construction phases, while the HWTT was performed only on RH-PMLC specimens. Each of these tests is briefly described in the following sub-sections.

Table 7 Laboratory Performance Testing Plan

Phase	Specimen type	Testing Party	Performance Tests		
			IDEAL-CT	HT-IDT	HWTT
Construction	H-PMLC	Contractor	X	X	
		ALDOT			
		NCAT	X	X	
	RH-PMLC	Contractor			
		ALDOT	X	X	X
		NCAT	X	X	X
Mix Design	LMLC	Contractor	X	X	
		ALDOT	X	X	

3.4.1 IDEAL-CT (AL-CT)

The IDEAL-CT test, adopted in Alabama as AL-CT, evaluates intermediate-temperature cracking resistance in accordance with ASTM D8225 (ASTM, 2019) and ALDOT-459 (ALDOT, 2022). Cylindrical gyratory specimens (150 mm × 62 mm) compacted to 7 ± 0.5% air voids were conditioned at 25°C (77°F) for 2 h. A monotonic load (Figure 5) was then applied at 50 mm/min until failure. Load–displacement data were used to calculate the CT_{Index} (Equation 1), which integrates failure energy, post-peak slope, and displacement at 75% of peak load. Higher CT_{Index} values indicate improved cracking resistance. Recent ALDOT special provisions (Appendix A) specify minimum construction-phase IDEAL-CT thresholds of 50 (ESAL A/B), 75 (ESAL C/D), and 100 (ESAL E).

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

where G_f = failure energy (J/m^2), m_{75} = Slope at 75% of post-peak load (kN/mm), l_{75} = Displacement at 75% post-peak load (mm), t and D = Specimen thickness and diameter (mm)

Figure 5 IDEAL-CT (AL-CT) test setup

3.4.2 High-Temperature Indirect Tensile Test

The HT-IDT test evaluates rutting resistance in accordance with ALDOT-458 (ALDOT, 2022b). Specimens (150 mm × 62 mm, 7 ± 0.5% air voids) were conditioned in a 50°C water bath for 1 hour, then loaded at 50 mm/min until failure (Figure 6).

Although ALDOT 458 specifies a conditioning period of 2 hours in a forced draft oven, this requirement has been found to be inadequate. In comparison, a similar ASTM standard requires 2.5 hours of conditioning in an air chamber or 45 minutes in a water bath (ASTM, 2022). For this project, a one-hour conditioning time in the water bath was followed, as internal research conducted at NCAT showed it was sufficient for achieving uniform temperature conditioning throughout the specimen.

The maximum load and specimen geometry were used to calculate HT-ITS (Equation 2). A minimum strength of 17 psi is required under ALDOT's special provisions (NAPA, n.d.).

$$HT-ITS = \frac{2 \times Max\ Load}{\pi \times D \times H} \qquad \text{Equation 2}$$

where: *HT-ITS* = High-Temperature Indirect Tensile Strength (psi), *Max Load* = The peak load during the test (lb.), *D* = Specimen diameter (in.), *H* = Specimen height (in.)

Figure 6 HT-IDT test setup

3.4.3 Hamburg Wheel Tracking Test

The HWTT, required by ALDOT for SMA and dense-graded mixes with high traffic, was performed in accordance with AASHTO T324 (AASHTO, 2023b). Pairs of gyratory specimens (150 mm × 62 mm, 7 ± 0.5% air voids) were submerged in a 50°C water bath and subjected to a 158-lb steel wheel load for 20,000 passes. Rut depth was recorded after 10,000 and 20,000 passes. Figure 7 shows a set of HWTT specimens after testing in this study.

Figure 7 HWTT Specimen after testing

3.5 Monitoring In-Service Performance of Test Sections

Construction was completed in April 2024. The project involved resurfacing 5,850 feet of SR-55, utilizing six test sections, each measuring 1,000 feet, with micro-milling followed by a 1.5-inch asphalt overlay. The existing pavement consisted of approximately 7.8 inches of asphalt layers resting on a 6-inch soil and aggregate base. The design traffic was estimated at 3.55 million Equivalent Single Axle Loads (ESALs) over a 20-year period, categorized as C/D traffic level.

Before the resurfacing, the pavement exhibited block cracking in the inner lanes, shallow rutting (ranging from 1/8 to 1/4 inch) across all lanes, and low-severity longitudinal cracking in the outer lanes. In December 2021, its Pavement Condition Rating (PCR) was recorded at 52. The last resurfacing of this roadway took place in 2009, which included a bituminous surface application followed by a leveling course of 0.75 inches and a 1.5-inch wearing surface.

Post-construction monitoring involved conducting surface condition surveys using NCAT's Pathway Van (Figure 8), which collected data on the International Roughness Index (IRI), rut depth, and macrotexture. Surveys were carried out before construction in 2022, immediately after paving in 2024, and again one year after construction in 2025. The field measurements were compared against laboratory performance indicators to evaluate correlations.

Figure 8 NCAT's Field Condition Survey Vehicle.

4. RESULTS AND ANALYSIS

4.1 BMD Performance Results

BMD test results for the six validation sections are presented in Table 8 using LMLC, H-PMLC, and RH-PMLC specimens.

Table 8 BMD Test Results for Validation Sections

Section	Specimen	Testing Party	CT_{Index}		*HT-ITS* (psi)		HWTT rut (mm) at 20K passes	
			Average	SD	Average	SD	Average	SD
#1	LMLC	Contractor	56.4	N/A	15.9	N/A	na	na
		ALDOT	75.0	14.5	13.8	2.0	na	na
	H-PMLC	Contractor	68.4	N/A	17.2	N/A	na	na
		NCAT	52.2	11.7	21.1	2.3	na	na
	RH-PMLC	ALDOT	37.8	5.0	36.7	4.5	3.42	N/A
		NCAT	33.9	9.3	27.3	3.1	4.88	0.16
#2	LMLC	Contractor	91.3	N/A	15.7	N/A	na	na
		ALDOT	109.6	24.8	18.2	3.4	na	na
	H-PMLC	Contractor	93.1	N/A	15.2	N/A	na	na
		NCAT	80.6	11.7	18.2	2.6	na	na
	RH-PMLC	ALDOT	63.0	11.4	42.0	2.9	3.86	N/A
		NCAT	54.4	8.3	24.1	1.9	4.75	1.30
#3	LMLC	Contractor	38.1	N/A	28.9	N/A	na	na
		ALDOT	34.4	5.6	24.7	7.0	na	na
	H-PMLC	Contractor	54.7	N/A	21.5	N/A	na	na
		NCAT	48.9	11.2	24.1	2.2	na	na
	RH-PMLC	ALDOT	28.9	5.8	53.9	6.7	2.87	N/A
		NCAT	12.2	3.1	47.6	11.1	1.83	0.31
#4	LMLC	Contractor	86.2	N/A	21.4	N/A	na	na
		ALDOT	111.0	1.1	24.3	3.7	na	na
	H-PMLC	Contractor	80.0	N/A	20.9	N/A	na	na
		NCAT	77.6	14.3	22.1	3.6	na	na
	RH-PMLC	ALDOT	46.7	9.5	41.9	1.8	3.74	N/A
		NCAT	34.4	3.8	35.8	5.0	3.63	0.92
#5	LMLC	Contractor	30.9	N/A	37.0	N/A	na	na
		ALDOT	35.1	3.5	44.3	6.4	na	na
	H-PMLC	Contractor	25.7	N/A	40.8	N/A	na	na
		NCAT	20.6	2.4	38.6	5.0	na	na
	RH-PMLC	ALDOT	20.4	3.9	77.0	6.7	2.00	N/A
		NCAT	11.4	2.4	60.6	0.8	1.46	0.22
#6	LMLC	Contractor	55.0	N/A	37.4	N/A	na	na
		ALDOT	71.3	9.1	37.7	4.6	na	na
	H-PMLC	Contractor	67.5	N/A	30.9	N/A	na	na
		NCAT	66.0	7.8	32.1	2.1	na	na
	RH-PMLC	ALDOT	33.5	6.0	47.0	5.8	2.35	N/A
		NCAT	27.3	7.2	48.1	1.9	1.63	0.03

Note: SD = Standard Deviation, na = Not Applicable, N/A = Not Available.

4.1.1 IDEAL-CT (AL-CT) Results

Figure 9 illustrates the comparison of CT_{Index} values among different specimen types: LMLC (measured by ALDOT with three replicates), H-PMLC (assessed by NCAT with five to six replicates), and RH-PMLC (also evaluated by NCAT with six replicates). The error bars indicate ±1 standard deviation. The average coefficients of variation (COVs) were 13.6% for LMLC, 16.9% for H-PMLC, and 21.1% for RH-PMLC specimens. Statistical analyses were conducted using one-way ANOVA followed by Tukey's HSD post hoc test at a significance level of $\alpha = 0.05$. The groupings are identified by different letter designations: capital letters for LMLC, lowercase letters for H-PMLC, and Greek symbols for RH-PMLC. Normality and homogeneity of variance assumptions were validated using the Anderson–Darling test and Levene's test.

The results show that all LMLC specimens tested by ALDOT met the respective target ranges for the test sections (Table 1). Generally, plant mixtures exhibited lower CT_{Index} values compared to laboratory-mixed specimens, and reheating further reduced their cracking resistance. The reductions in CT_{Index} values from LMLC to RH-PMLC ranged between 50.4% and 69.0%, with an average reduction of 61.3%. Despite these declines, the relative performance rankings were consistent; high-CT_{Index} designs (Sections 2 and 4) consistently outperformed low-CT_{Index} designs (Sections 3 and 5). These findings suggest that while absolute threshold values may vary depending on specimen preparation and aging, the relative rankings remain the same.

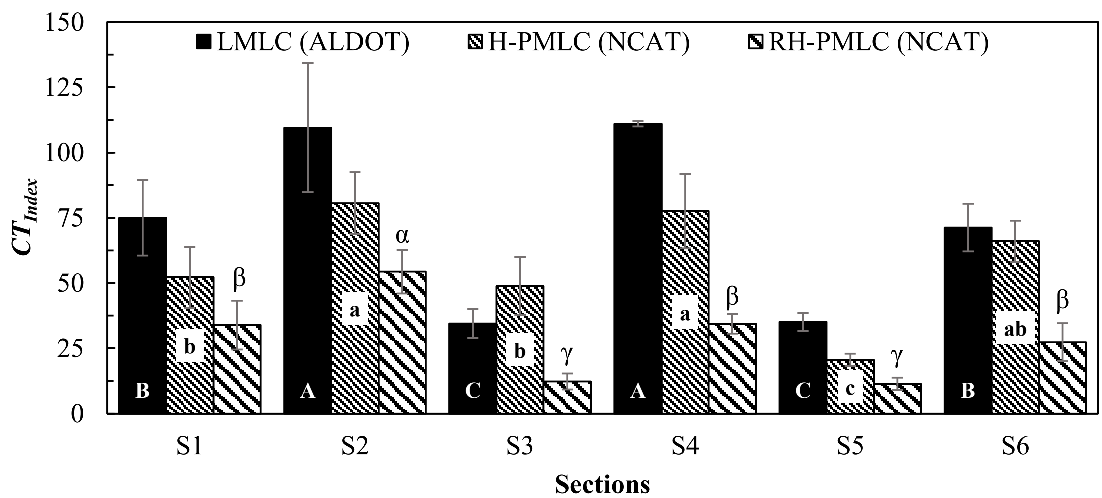


Figure 9 IDEAL-CT CT_{Index} Validation Sections

Figure 10 presents corresponding failure energy (G_f)values. Average COVs were 8.1% for H-PMLC and 6.1% for RH-PMLC specimens. Unlike CT_{Index}, G_f exhibited fewer significant differences among mixtures, and in some cases, RH-PMLC specimens yielded similar or even higher G_f values than H-PMLC specimens. This counterintuitive trend suggests that CT_{Index} reductions are primarily driven by changes in the $l_{75}/|m_{75}|$ ratio with aging, reaffirming CT_{Index} as a more sensitive indicator of cracking performance than G_f.

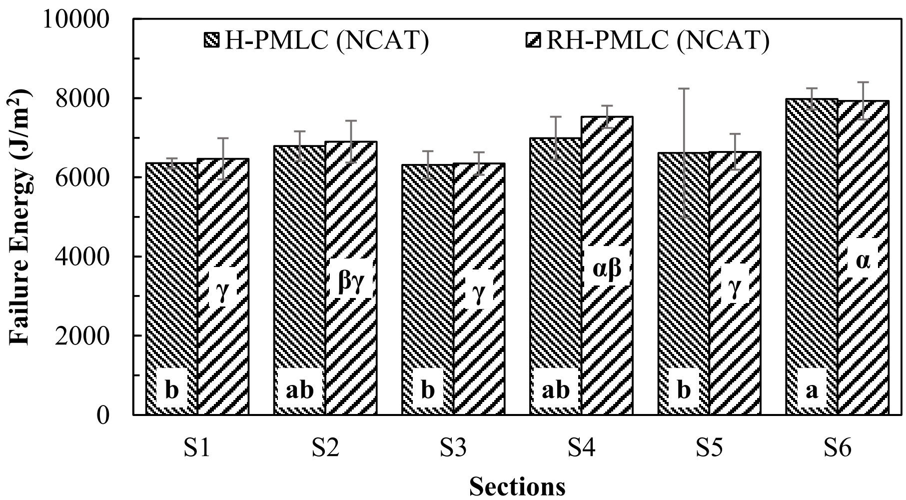


Figure 10 IDEAL-CT Failure Energy Values

4.1.2 HT-IDT Results

Figure 11 shows *HT-ITS* results for LMLC, H-PMLC, and RH-PMLC specimens, with three, four, and four replicates per mix, respectively. Error bars represent ±1 standard deviation. Average COVs were 17.2% for LMLC, 11.6% for H-PMLC, and 10.3% for RH-PMLC. Statistical comparisons were again conducted using ANOVA with Tukey's HSD at α = 0.05.

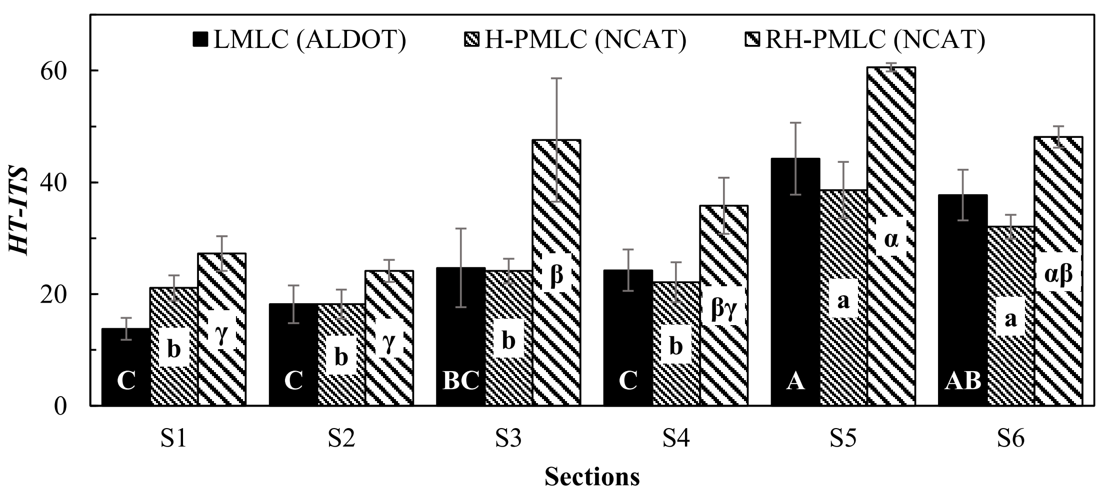


Figure 11 HT-ITS for Validation Sections

The results indicated that H-PMLC specimens generally yielded *HT-ITS* values that were similar to or slightly lower than those of LMLC specimens, while RH-PMLC specimens consistently showed higher *HT-ITS* values. This increase is attributed to the effects of reheating, which enhance rutting resistance. The increases from LMLC to RH-PMLC ranged from 27.5% to 97.9%, with an average increase of 55.9%. Similar to the IDEAL-CT findings, the relative ranking of mixtures remained consistent, with high-HT-ITS designs (Sections 5 and 6) outperforming low-HT-ITS designs

(Sections 1 and 2). These results suggest that while specimen preparation can affect the absolute values, the relative comparisons among mixtures remain the same.

4.1.3. HWTT Results

Figure 12 summarizes HWTT rut depths measured after 10,000 and 20,000 passes for RH-PMLC specimens tested at NCAT. Error bars represent ±1 standard deviation, with average COVs of 13.4% and 15.0% for rut depths measured at 10,000 and 20,000 passes, respectively. Because only two pairs of specimens were available for each mix, statistical groupings were not performed.

The observed rutting trends were consistent with the results from the HT-IDT test. Mixtures with higher HT-ITS values, specifically in Sections 5 and 6, showed the lowest rut depths, confirming their superior resistance to rutting. All mixtures met the performance thresholds set by ALDOT for 10-30 million ESAL traffic, with rut depths remaining below the 10 mm limit after 10,000 passes for PG 67-22 binders (ALDOT, 2022b). These findings emphasize the reliability of both HT-IDT and HWTT in assessing rutting performance.

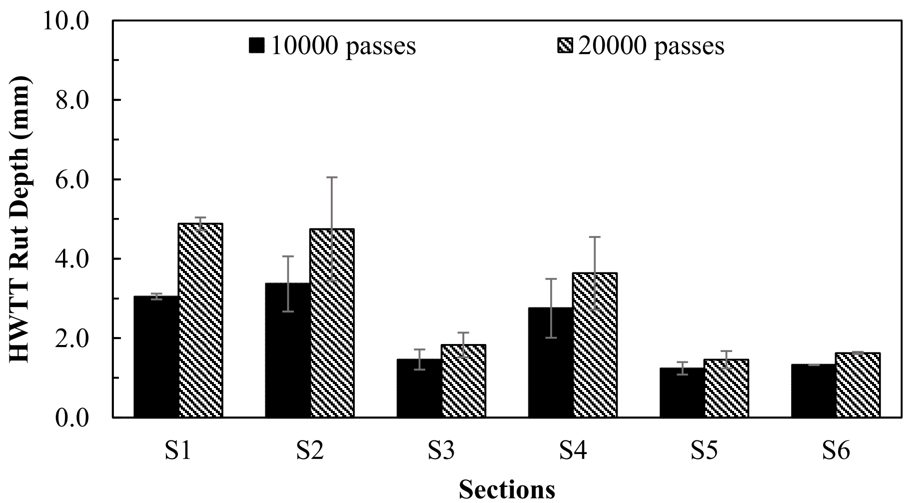


Figure 12 HWTT Rut Depth for Validation Sections

4.2 Correlation of BMD and Volumetric Properties

Pearson correlation analysis was conducted to investigate the relationships between changes in volumetric properties and changes in BMD performance test results during the mix design and production. The variables analyzed included CT_{Index}, *HT-ITS*, asphalt content (AC%), voids in mineral aggregate (VMA), effective binder content (P_{be}), and the Primary Control Sieve Index (PCSI). A correlation coefficient exceeding |0.6| was considered strong, while a coefficient exceeding |0.8| was regarded as very strong.

As shown in Table 9, a strong negative correlation of -0.71 was found between the changes in CT_{Index} (ΔCT_{Index}) and the changes in *HT-ITS* (Δ*HT-ITS*), which is consistent with the expected correlations between cracking and rutting resistance. Additionally, a very strong positive correlation of 0.85 was observed between ΔPCSI and ΔVMA, highlighting the influence of aggregate gradation on volumetric structure (Leiva & West, 2021). However, no strong correlations were identified between the volumetric properties and either the BMD performance test result, which emphasizes the limited predictive capability of volumetric parameters and underscores the necessity for direct performance testing within the BMD framework.

Table 9 Correlation of Changes in Volumetric Properties and Changes in BMD Test Results

	Δ CT_{Index}	**Δ *HT-ITS***	**Δ AC**	**Δ VMA**	**Δ P_{be}**
Δ *HT-ITS*	-0.711				
Δ AC	0.294	-0.005			
Δ VMA	-0.344	0.313	0.161		
Δ P_{be}	-0.099	-0.392	0.423	0.138	
Δ PCSI	-0.394	0.477	-0.071	0.853	-0.284

4.3 Field Survey Results

Field surveys were conducted at three times: December 2022 (pre-construction), April 2024 (immediately after construction), and April 2025 (one year after construction). These datasets offer insights into early field performance, and long-term performance data will be continuously monitored. Three surface condition indicators were evaluated: (1) roughness via International Roughness Index (IRI), (2) macrotexture via Mean Profile Depth (MPD), and (3) rut depth. No cracking was observed during this early period.

4.3.1. Field Performance: Roughness Results

Figure 13 presents average IRI values across validation sections. Roughness levels were consistent among sections at all three survey times. Post-construction IRI values (2024) primarily reflected construction quality rather than material performance. All sections would have qualified for ride quality bonus pay according to ALDOT's ride quality specifications (ALDOT, 2022b). Between 2024 and 2025, IRI increased modestly (2.9–15.3%), but no systematic trends were associated with mixture cracking or rutting categories. Continued monitoring is required to assess whether long-term roughness differences emerge.

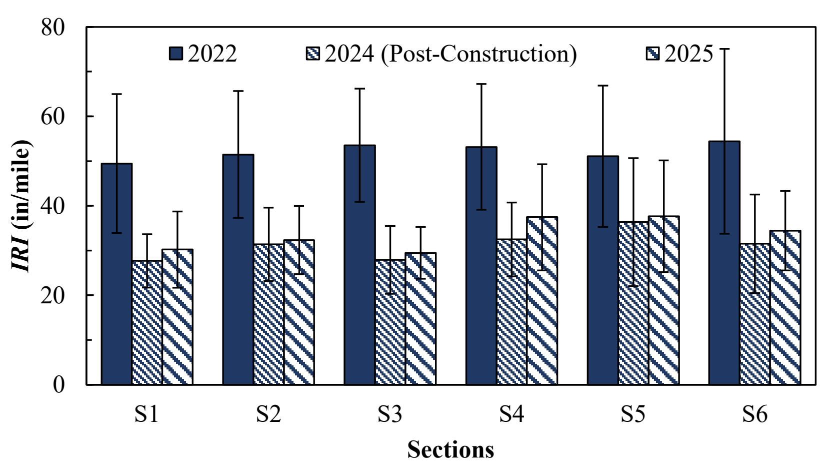


Figure 13 Field IRI Results for Validation Sections

4.3.2. Field Performance: Macrotexture Results

Figure 14 shows MPD values, which were comparable across sections with no systematic differences. In 2025, MPD ranged narrowly from 0.47 to 0.51 mm, suggesting that macrotexture did not differentiate performance among mixtures during the first year of service.

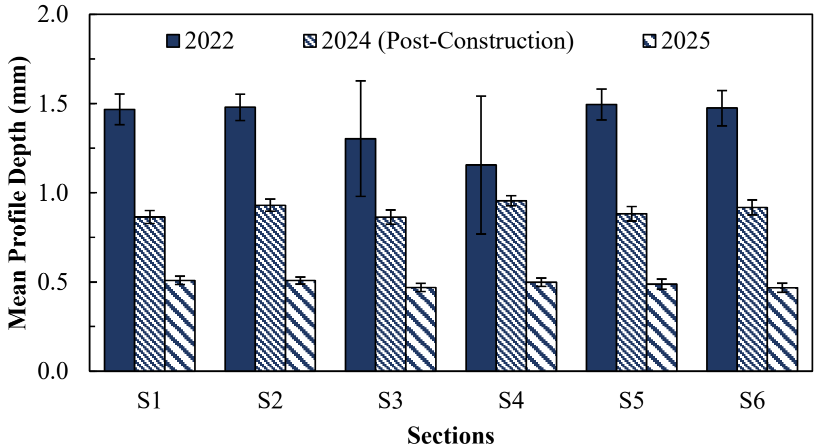


Figure 14 Field MPD Results for Validation Sections

4.3.3. Field Rut Depths

Figure 15 presents average rut depths across sections. Pre-construction rut depths (2022) exceeded 0.4 in., with minimal variation. Immediately after construction (2024), rut depths were uniformly low across sections, consistent with expectations. By 2025, differences became evident: mixtures designed for higher rutting resistance in the laboratory (Sections 5 and 6) exhibited lower field rut depths, aligning laboratory and field results.

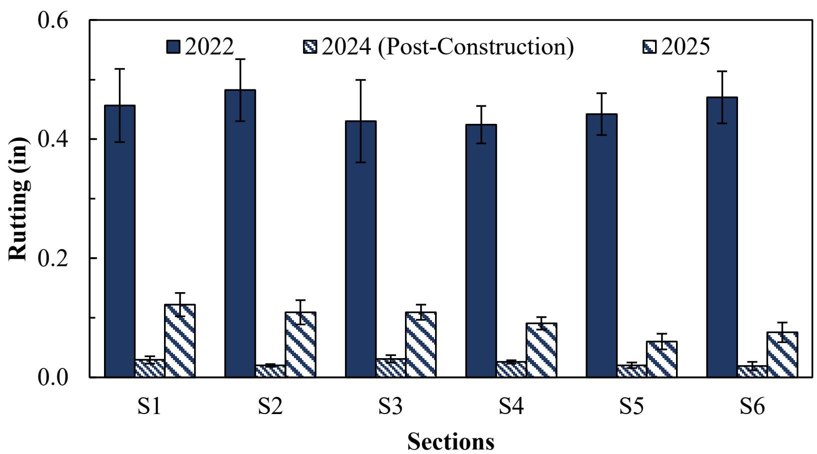


Figure 15 Field Rut Depths for Validation Sections

Figure 16 provides rut depth profiles by 25-ft intervals. Section boundaries are indicated by vertical lines, and dashed lines represent moving averages. The 2025 profiles clearly show performance separation among low-, medium-, and high-rutting resistance mixtures, particularly in the high-HT-ITS sections.

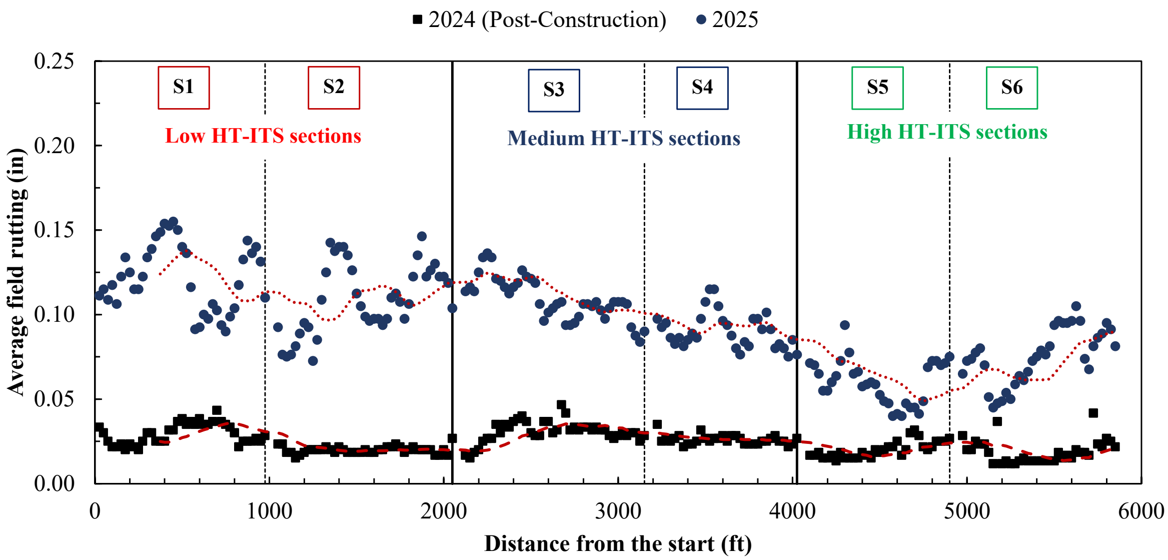
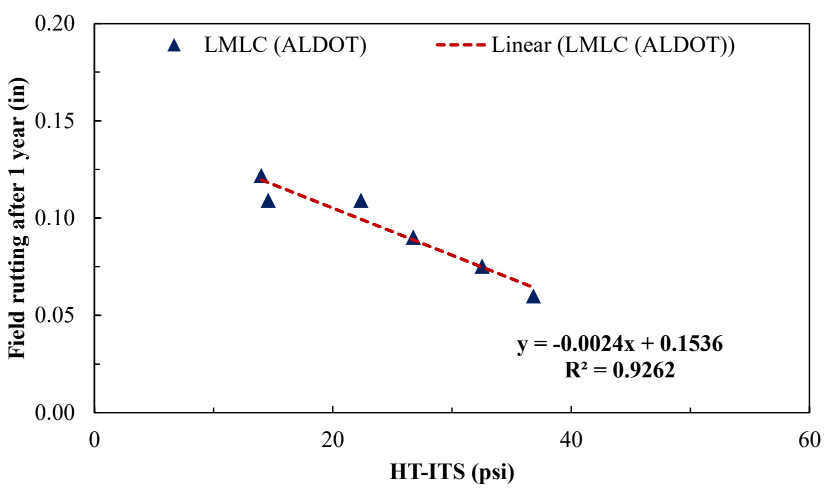


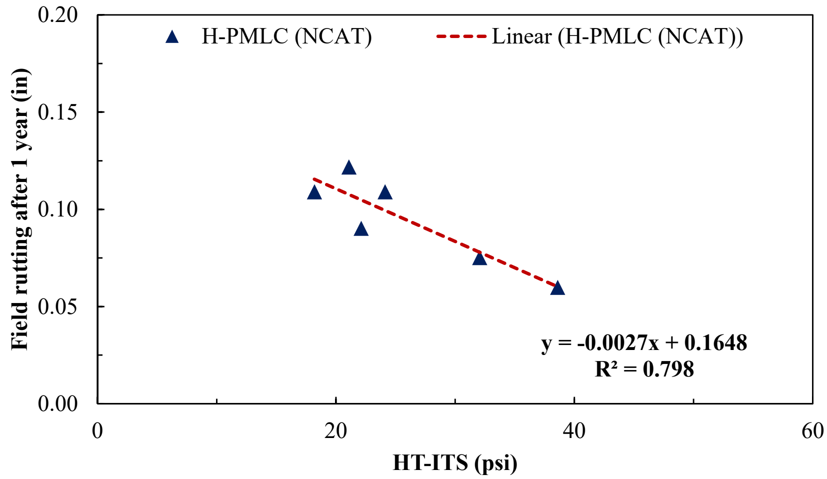
Figure 16 Field Average Rutting for 25-Ft Intervals within Validation Sections.

4.4 Correlation between Laboratory and Field Performance

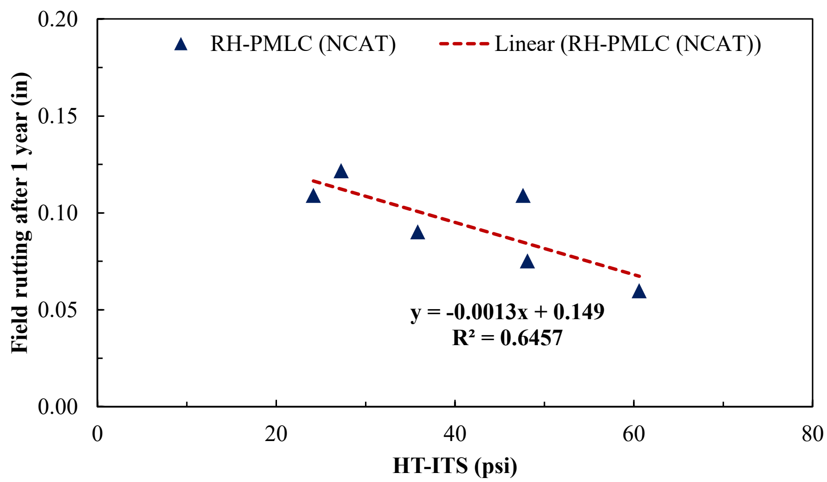
Given that roughness and macrotexture did not differentiate mixture performance, correlations focused on rutting. Figure 17 illustrates relationships between one-year field rut depths (2025 survey) and HT-ITS results from LMLC, H-PMLC, and RH-PMLC specimens. Strong to very strong negative correlations were observed, with the strongest correlation for LMLC specimens (R^2 = 92.6%). These results demonstrate that HT-IDT is an effective predictor of early rutting resistance. The test's simplicity, speed, and relatively low variability compared with other rutting tests strengthen its role in the BMD framework.



a) *HT-ITS* of ALDOT's LMLC Specimens versus One-Year Field Rut Depths



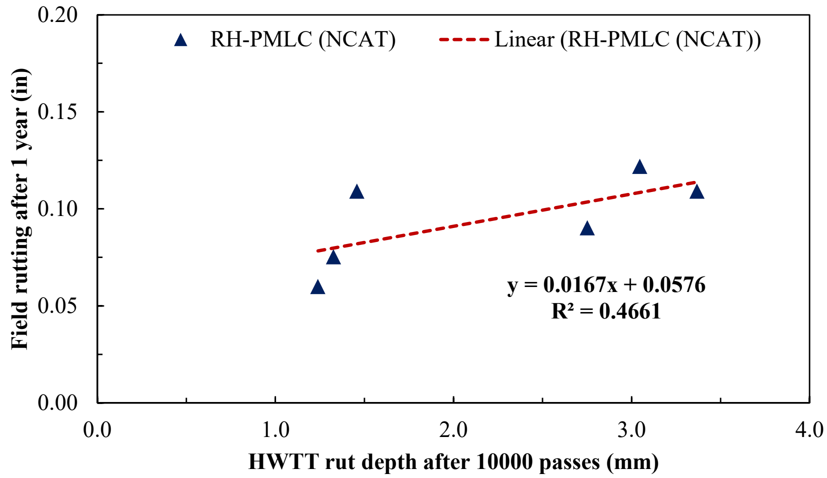
b) *HT-ITS* of NCAT's H-PMLC Specimens versus One-Year Field Rut Depths



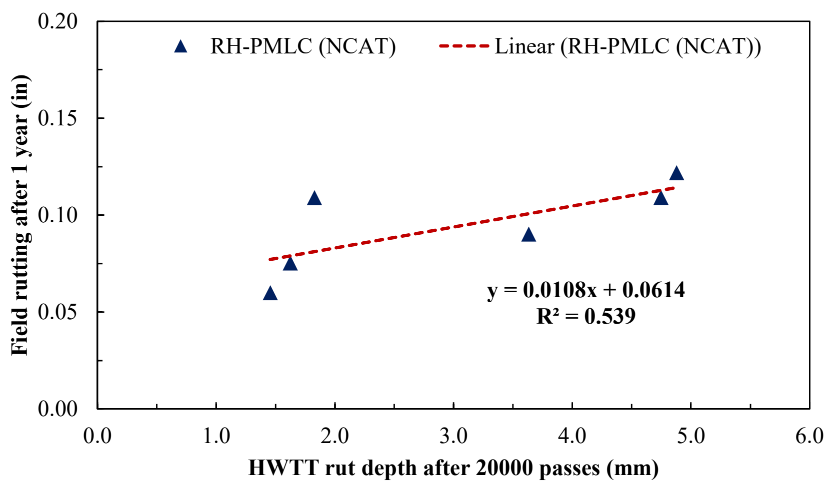
c) *HT-ITS* of NCAT's RH-PMLC Specimens versus One-Year Field Rut Depths

Figure 17 Correlation of Field Rut Depths and HT-ITS.

Figure 18 shows correlations between field rutting and HWTT rut depths. Moderate positive correlations were observed, with the strongest (R^2 = 53.9%) for rut depth after 20,000 passes. While HWTT also predicted acceptable early rutting performance, correlations were weaker than those for HT-IDT.



a) Rutting after 10000 HWTT passes



b) Rutting after 20000 HWTT passes

Figure 18 Correlation of Field Rutting and HWTT Rut Depth.

Overall, these results provide early validation for the BMD mix designs and performance criteria. Strong correlations between laboratory rutting indicators and early field performance confirm the effectiveness of the HT-IDT and HWTT tests within BMD. Continued monitoring will be essential to determine whether these relationships hold over time, especially once field cracking occurs, and can be compared with IDEAL-CT results. Such evidence will be critical for advancing the implementation of BMD specifications in Alabama and beyond.

5. SUMMARY AND CONCLUSIONS

This study implemented and evaluated the principles of Balanced Mix Design (BMD) through the design, construction, and field monitoring of six validation sections on SR-55 in Alabama. The main objective was to validate laboratory performance test thresholds, particularly for rutting resistance, by comparing them against short-term field performance. Additionally, the study aimed to provide evidence for refining ALDOT's BMD special provisions. The key outcomes are summarized as follows:

5.1 Laboratory Performance Test Results

Specimen types significantly affected measured performance. Laboratory-mixed, laboratory-compacted (LMLC) specimens consistently produced higher CT_{Index} values than plant-produced specimens, while reheated plant-mixed, lab-compacted (RH-PMLC) specimens showed further reductions, confirming the adverse effects of reheating on cracking resistance.

In contrast, the values for *HT-ITS* increased with reheating, indicating enhanced resistance to rutting. Although there were some differences based on the types of specimens, the overall ranking of the mixtures remained consistent across different specimen types. This suggests that laboratory thresholds may need to be adjusted according to specimen type, but the comparative performance of the mixtures is still reliable.

5.2 Volumetric vs. Mechanical Properties

Correlation analyses indicated that volumetric properties alone are inadequate predictors of laboratory-measured cracking or rutting resistance. Significant correlations were only found between ΔPCSI and ΔVMA, as well as between ΔCT_{Index} and Δ*HT-ITS*. These correlations suggest the influence of aggregate structure and the inherent correlations between cracking and rutting performance. These findings emphasize the limitations of traditional volumetric mix design and underscore the importance of incorporating direct performance testing in BMD specifications.

5.3 Early Field Performance

After one year of service, no cracking was observed in any section, and there were no significant variations in roughness or macrotexture among the different mixtures. However, rutting trends did show differences in performance. Sections designed with higher HT-ITS thresholds demonstrated lower rut depths in the field, confirming that laboratory results were aligned with early field performance in terms of rutting.

5.4 Laboratory Test Results and Field Performance Correlations

Strong to very strong negative correlations were observed between one-year field rutting and HT-ITS results, particularly for LMLC specimens (R^2 = 92.6%). HWTT rut depths were also correlated with field rutting, with stronger relationships with rut depths measured at 20,000 wheel passes ($R^2 \approx$ 54%) than those measured at 10,000 passes. These results demonstrate that HT-IDT, and to a lesser degree HWTT, are effective indicators of early rutting performance, supporting their inclusion in BMD practice.

5.5 Implementation

The study provides early validation of BMD as a practical framework for improving mixture durability in Alabama. Laboratory performance tests, particularly HT-IDT, were shown to reliably predict early rutting resistance observed in service. Continued field monitoring is essential to capture long-term rutting progression and, critically, the onset of cracking so that IDEAL-CT thresholds can be validated under traffic and climate conditions representative of Alabama.

In summary, this field validation demonstrates that BMD improves the reliability of asphalt mixture design by directly linking laboratory performance tests to field outcomes. While specimen preparation effects must be considered when setting thresholds, the relative ranking of mixtures is robust across specimen types. The absence of cracking during the first year underscores the need for continued monitoring, but the strong agreement between laboratory and early field rutting performance provides compelling evidence for the broader adoption of BMD specifications. Long-term performance data from these sections will further guide ALDOT in refining thresholds, ensuring durable and cost-effective pavements for Alabama.

6. REFERENCES

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APPENDIX A: ALDOT JOB SPECIAL PROVISION

ALABAMA DEPARTMENT OF TRANSPORTATION

Project Specific Special Provision

DATE: June 23, 2022 Special Provision No. XXXXX

SUBJECT: Asphalt Pavement - Balanced Mix Design ESAL Range C/D Benchmarking Sections
Project No. XXXX), YYYY County

Alabama Standard Specifications, 2022 Edition, SECTION 106, SECTION 410, and SECTION 424 shall be revised as follows:

This Project Specific Special Provision applies only to the trial sections for Balanced Mix Design (BMD) validation as designated in the plans. These trial sections shall conform to the plans and specifications except as noted below. Each test section's plant mix will have different IDEAL-CT and HT-IDT test score requirements so that the results can be compared to rutting and cracking performance on the roadway to validate preliminary BMD criteria or to adjust those criteria. To fulfill this requirement, the contractor may design several different mixes including changing types, sources, and blend proportions of aggregates, liquid asphalt, RAP, RAS, and additives. The contractor will have the option to use a number of design gyration other than 60 as approved by the engineer. Since these sections are for validation purposes, the IDEAL-CT and HT-IDT test score requirements will be treated as target score ranges, not minimum scores. The mixtures for these trial sections will be paid at 100% of the bid price if they are produced and constructed with asphalt binder content and gradation within the specified tolerances of the mix design. Since these are research trial sections, the mixtures will be sampled thoroughly and frequently by ALDOT's central laboratory and The National Center for Asphalt Technology at Auburn University (NCAT) in addition to the normal sampling and testing required for QC/QA.

SECTION 106
CONTROL OF MATERIALS

106.09 Quality Control and Quality Assurance (QC/QA) Requirements for Hot Mix Asphalt (HMA) Pavement.

(b) Quality Control.

The portion of Table 1 concerning Section 424 mixes shall be replaced with the following:

TABLE I (*CONT'D.*) SECTION 424 MIXES (***SUPERPAVE***)
SAMPLING AND TESTING REQUIREMENTS FOR QC/QA PROJECTS

Control Parameter	Sample Size	Sampling Methods	Sampling Location	Testing Methods	ALDOT Testing Frequency	Contractor Testing Frequency
1.Asphalt Content *	ALDOT Sample = 135 lb {60 kg} Split into 2 equal samples	AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT-354 or AASHTO T 308 ++++	1 per day per LOT	++ 1 per trial section
2. Maximum Specific Gravity *		AASHTO T 168 & ALDOT-210	+Loaded Truck	AASHTO T 209 (Flask determination with dry back)	1 per day per LOT	++ 1 per trial section
3. Air Void Content& VMA	Contractor Sample = 135 lb {60 kg} Split into 2 equal samples	AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT-384 ALDOT-388 ALDOT-370	1 per day per LOT	++ 1 per trial section
% G_{mm} @ N_d *					As needed	
4. Mixture *** Gradation & Dust to Asphalt Ratio *		AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT-371 AASHTO T 308	1 per day per LOT	++ 1 per trial section
5. Retained Tensile Strength Note: The TSR test is not required for any pay item less than a full lot.	25 lb. {12 kg}	AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT-361	1 set of 6 for the first full lot (2,800 tons {2,800 metric tons}) and 1 set of 6 for the next 10,000 tons {10,000 metric tons} and 1 set of 6 for each additional 20,000 tons {20,000 metric tons} or portion thereafter	1 set of 6 for the first full lot (2,800 tons {2,800 metric tons}) and 1 set of 6 randomly for the next 10,000 tons {10,000 metric tons} and 1 set of 6 for each additional 20,000 tons {20,000 metric tons} or portion thereafter
6. Mat Density *		ALDOT-210	Roadway	ALDOT-222 & ALDOT-350		As per the Contractor's QC plan (ALDOT-375) 1 per trial section
				ALDOT-403 AASHTO T 166 Method A AASHTO T 275 AASHTO T 331	°° 1/3,000 lane feet/lift {1/900 lane m/lift} or 1 per trial section	

TABLE I (*CONT'D.*)			SECTION 424 MIXES SAMPLING AND TESTING REQUIREMENTS FOR QC/QA PROJECTS			(*SUPERPAVE*)
Control Parameter	Sample Size	**Sampling Methods**	**Sampling Location**	**Testing Methods**	**ALDOT Testing Frequency**	**Contractor Testing Frequency**
7. Fine Aggregate Angularity * * FAA Note: The FAA test is not required for any pay item less than a full lot.	Adequate quantity to run AASHTO T 304, Method A or ASTM C 1252,Method A	AASHTO T 2	+Loaded Truck	AASHTO T 304, Method A Or ASTM C 1252, Method A	1 for the first full lot (2,800 tons {2,800 metric tons}) and 1 for the next 10,000 tons {10,000 metric tons} and 1 for each additional 20,000 tons {20,000 metric tons} or portion thereafter	1 for the first full lot (2,800 tons {2,800 metric tons}) and 1 randomly for the next 10,000 tons {10,000 metric tons} and 1 randomly for each additional 20,000 tons {20,000 metric tons} or portion thereafter
8. Clay Content	Adequate quantity	AASHTO T 2	Stockpile	AASHTO T 176	As required	As required
9. Asphalt Draindown	12 lb {5kg}	AASHTO T 168 & ALDOT-210	+Loaded Truck	AASHTO T 305	As Required	As Required
10. Split Tensile *X*	35 lb. {17 kg}	AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT 361 (Report the Unconditioned Sample for Split Tensile)	N/A	1 for the first full lot and 1 randomly for each additional 10,000 tons thereafter
11. Resistance to Cracking	100 lb. {45 kg}	AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT 459	1 per test section	1 per test section
12. Resistance to Rutting		AASHTO T 168 & ALDOT-210	+Loaded Truck	ALDOT 458	1 per test section	1 per test section

TABLE I (*CONT'D.*) **SECTION 424 MIXES** **(*SUPERPAVE*)**

SAMPLING AND TESTING REQUIREMENTS FOR QC/QA PROJECTS

* See ALDOT 370 "Quality Control and Quality Assurance Procedures and Responsibilities for Asphalt Plant Mix Production".

* * In virgin mixes, the sample may be taken from the cold feed conveyor.

*** If the test results are out of specification tolerance on two consecutive tests for the same size sieve, production shall cease until proper plant adjustments are made.

•• Cores shall be taken by the Contractor and the density will be determined by the Department.

\+ Beginning each production day, no sample for acceptance purposes shall be taken prior to the production of 50 tons. If the random number selected falls within the first 50 tons, the sample shall be taken from the first loaded truck following the truck containing the fiftieth ton produced.

++ The sample shall be one set of two gyratory samples+++.

+++ When slag is used as an aggregate in the mixture, three gyratory samples shall be compacted. The test result the furthest away from the average of the three test results shall be discarded and the remaining two test results shall be averaged for use in the computation of air voids.

++++ Under AASHTO T 308, mixture calibration shall be used. The ignition furnace shall be equipped with an internal weighing system with microprocessor control where sample weight {mass} and percent weight {mass} loss is computed and produced on hard-copy output.

X Testing in accordance with the requirements given in Section 410 is only required for Job Mix Formulas that have greater than 25 % RAP. Mix shall be tested by an AASHTO accredited laboratory.

SECTION 410
ASPHALT PAVEMENTS

410.02 Materials.

(e) Recycled Asphalt Plant Mix (RAP) and Reclaimed Asphalt Shingles (RAS).

2. Allowable Usage of RAP and RAS.

The table shall be replaced with the following:

ALLOWABLE USE OF RAP AND RAS Maximum Allowable Percent of RAP and RAS by mass of Total Aggregate Content		
Type of Mix	Maximum RAP Content #	Maximum RAP and RAS Content **
327, Plant Mix Bituminous Base	25 %	RAS Not Allowed
327-E, Permeable Asphalt Treated Base	10 %	RAS Not Allowed
420, Open Graded Friction Course	0 %	RAS Not Allowed
423, Stone Matrix Asphalt	Surface Layers: 20 % with no more than 15 % containing chert *; All Other Layers: 35 %	Surface Layers: 20 % *; All Other Layer: 35%
424, Superpave (Maximum Aggregate Size ½", ¾", 1", 1 ½")	Surface Layers: 35 % + All Other Layers 100%	Surface Layers: 35% + All Other Layers 100%
424, Superpave (Maximum Aggregate Size 3/8")	Surface Layers: 35 % +	RAS Not Allowed***
* This limitation applies even if the surface layer is to be covered by an Open Graded Friction Course (Section 420). If the aggregate is chert gravel with a bulk specific gravity that is less than 2.550, a maximum of 15 % of the RAP will be allowed. RAP containing chert gravel shall be crushed so that 100 % of the RAP passes the 1/2 inch {12.5 mm} sieve. Additional RAP that does not contain chert gravel may be added to the mixture through a separate feeder. ** RAS shall be limited to 3% by mass of the total aggregate content for surface layers and 5 % by mass of the total aggregate content for all other layers. *** For projects where the ADT is less than 100 or the surface to be paved is non-trafficked, RAS may be allowed at the contents given for the other 424 Superpave maximum aggregate sizes. + RAP contents greater than those listed as maximum in this table will be allowed on the condition that The High RAP mix must have a DFT number that is at least 94% that of the same mix with a RAP content that is below the listed threshold when tested by three wheel polishing and Dynamic Friction Testing According to ASTM E1911. NOTE: RAS will be allowed in BMD trial sections as long as target BMD test scores are met.		

410.03 Construction Requirements.

(a) Equipment.

4. Asphalt Pavers or Spreaders.

The fourth paragraph of Item 410.03(a)4 shall be replaced with the following:

All asphalt paving machines shall be operated with automatic grade and slope controls unless otherwise directed by the Engineer. (The Engineer will not require operation with automatic slope controls when the requirement for "Match Existing" is given on the plans for the required finished cross slope.) The automatic grade controls shall be a contact ski, a mobile stringline, or non-contact sonic averaging sensors. The effective length of these controls shall be a minimum of 24 feet {7.3 m}. In the event of a malfunction of the automatic control system, the spreading operation shall be discontinued after one hour until the equipment is repaired.

410.08 Method of Measurement.

(e) Acceptance of the Roadway Density.

After the asphalt mixture has been placed and compacted, it shall be evaluated for density. A core for mat density determination shall be taken by the Contractor on each test section. The location of each test will be designated by the Department. The core shall meet a minimum thickness for use in determining the roadway density. If the core's average thickness in inches is not at least 0.008 times the rate in pounds per square yard, another core shall be taken (as close as practical to the original location) where the Engineer believes the pavement is thick enough for roadway density determination. The core's average thickness shall be determined by measuring the core's thickness at six equidistant locations around the circumference of the core. The Department will take immediate possession of the core and will make a density determination of the core in accordance with AASHTO T 166, Method A. Testing locations will be selected with the random number method outlined in ALDOT-210. Contractors are allowed, but not required, to take cores anywhere, anytime for quality control. This includes taking cores from the wearing layer. All core holes shall be promptly repaired at the contractor's expense

The in-place density will be expressed as a percentage of the theoretical maximum density (TMD) of the mix with the following relationship:

$\% \mathbf{TMD} = \frac{\textbf{In Place Density}}{\textbf{Maximum Mix Density}} \times \mathbf{100}$Maximum mix density is equated to maximum mix specific gravity as measured with AASHTO T 209, Flask determination with dry back. The maximum mix specific gravity used will be the average of the values from the four most recent determinations using Contractor data.

%TMD as described above shall be no less than 93% and no greater than 95%. Any Mix outside this tolerance shall be removed and replaced with mix that is in tolerance.

Table V shall be replaced with the following.

TABLE V COMPARISON OF ALDOT AND CONTRACTOR TESTING	
TEST	ACCEPTABLE
ASPHALT CONTENT	± 0.30 %
AIR VOIDS	± 0.50 %

SECTION 424
SUPERPAVE BITUMINOUS CONCRETE BASE, BINDER, AND WEARING SURFACE LAYERS

424.02 Materials.

(a) Aggregates.

8.Clay Content for Superpave

Item 424.02(a)8 shall be replaced with the following:

8. Blank.

(c) Blend of Aggregates.

1. Gradations for Blend of Aggregates.

The coarse and fine aggregates, mineral filler, and recycled material shall be combined in a total blend that will produce an acceptable job mix within the gradation limits determined by the maximum and minimum control points as shown in the following tables. Maximum particle size is defined as the sieve size that is two sizes larger than the first sieve to retain more than 10 % of the material. The sequence of sieve sizes to be used in determining maximum particle size is given in the following tables. Gradation charts illustrating gradation requirements are given in Article 424.03.

The required mix will be shown on the plans. All ALDOT-424 ESAL range "E" Wearing Surface Layer and Upper Binder Layer mixes shall be tested for susceptibility to rutting in accordance with the latest approved version of AASHTO T 324 Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures. All Mixes shall be tested at 50°C in water. ALDOT 424 ESAL Range E mixes using PG 67-22 binder shall exhibit 10 mm rutting or less at 10,000 cycles. ALDOT 424 ESAL Range E mixes using PG 76-22 binder shall exhibit 10 mm rutting or less at 20,000 cycles.

AGGREGATE GRADATION CONTROL POINTS FOR SUPERPAVE 1 1/2 inch {37.5 mm} Maximum Aggregate Size Mix		
	Control Point (Percent Passing)	
Sieve Size	Minimum	Maximum
1.5" {37.5 mm} Maximum	100	-
1" {25 mm} Nominal	90	100

AGGREGATE GRADATION CONTROL POINTS FOR SUPERPAVE 1 inch {25.0 mm} Maximum Aggregate Size Mix		
	Control Point (Percent Passing)	
Sieve Size	Minimum	Maximum
1" {25 mm} Maximum	100	-
3/4" {19 mm} Nominal	90	100

AGGREGATE GRADATION CONTROL POINTS FOR SUPERPAVE 3/4 inch {19.0 mm} Maximum Aggregate Size Mix		
	Control Point (Percent Passing)	
Sieve Size	Minimum	Maximum
3/4" {19.0 mm} Maximum	100	-
1/2" {12.5 mm} Nominal	90	100

AGGREGATE GRADATION CONTROL POINTS FOR SUPERPAVE 1/2 inch {12.5 mm} Maximum Aggregate Size Mix		
	Control Point (Percent Passing)	
Sieve Size	Minimum	Maximum
1/2" {12.5 mm} Maximum	100	-
3/8" {9.5 mm} Nominal	90	100

AGGREGATE GRADATION CONTROL POINTS FOR SUPERPAVE 3/8 inch {9.5 mm} Maximum Aggregate Size Mix		
	Control Point (Percent Passing)	
Sieve Size	Minimum	Maximum
3/8" {9.5 mm} Maximum	95	100
No. 4 {4.75 mm} Nominal	75	100
Note: Up to 5% may be retained on the maximum size sieve (3/8 inch {9.5 mm}) and up to 25% may be retained on the nominal size sieve (#4 {4.75 mm}).		

2. Blank
3. Blank
4. Restrictions in the use of Carbonate Stone for Blend of Aggregates.

The restrictions for the use of carbonate stone are given in the following table. These restrictions do not apply to widening as defined in Article 410. 01, shoulder paving, underlying layers, and layers that are to be covered by Polymer Modified Open Graded Friction Course (Section 420) mix in this contract.

CRITERIA FOR THE USE OF CARBONATE STONE IN SUPERPAVE	
BPN 9 Value Of Aggregate Source *	Maximum Allowable Percentage Of Carbonate Stone
20 or less	Not Allowed
21 through 25	30
26 through 28	35
29 through 31	40
32 through 34	45
35 or higher	50
* This value, BPN 9, is made using the British Pendulum Tester on aggregate source specimen polished for 9 hours on an accelerated polishing machine known as the British Wheel as per ASTM D 3319, ASTM E 303 and ALDOT-382.	

In no case shall the total amount of carbonate stone in the combined mixture used as actual wearing surface layers that are exposed to traffic exceed the percentage shown in the above table. When parts of the carbonate stone used in the mix are from differing strata of material or coming from multiple sources that are represented by different BPN 9 values, the lowest BPN 9 value will be used.

(d) Liquid Asphalt Binder.

Article 424.02(d) shall be replaced by the following:

(d) Liquid Asphalt Binder.

Liquid asphalt binders shall come from an approved producer who is participating in and meeting the requirements of ALDOT-243, *Acceptance Program For Asphalt Materials*. The producer's name shall be listed in the Department's *Materials, Sources, and Devices With Special Acceptance Requirements* Manual, List I-4. The Department has established a list of qualified producers of asphalt materials. Refer to Subarticle 106.01(f) and ALDOT-355 concerning this list. Unless shown otherwise on the plans or in the proposal, liquid asphalt binder for use in all mixes shall meet the requirements of AASHTO M 320, *Standard Specification For Performance Graded Asphalt Binder*, as modified by the requirements given in the following table and Section 804. The Supplier of the liquid asphalt binder used in design shall be used during construction.

ALLOWABLE ASPHALT BINDER GRADES FOR SUPERPAVE			
ESAL Range	Traffic (ESALs)	Base, Lower, & Upper Binder Layers	Wearing Surface Layers
A/B	ESALs < $1.0x10^6$	PG 67-22	PG 67-22
C/D	$1.0x10^6$ < ESALs < $1.0x10^7$	PG 67-22	PG 67-22
E	$1.0x10^7$ < ESALs < $3.0x10^7$	PG 67-22	PG 76-22*
*The asphalt binder shall be PG 76-22 for leveling when the top of the leveling is within 2 inches {50 mm} of the final pavement surface. The asphalt binder may be PG 67-22 for leveling that is not within 2 inches {50 mm} of the final pavement surface and for all patching and widening. If Open Graded Friction Course (Section 420) layers are required, the final pavement surface shall be the surface of the layer below these layers.			

Note: Other binder Grades will be considered on a case by case basis if they improve the performance of the mix as determined by the tests in Section 424.02 (e).

Asphalt Binders shall meet the requirements of Section 804.

Polymer modifiers shall be blended at an approved refinery and meet the requirements of Section 811. Approved Warm Mix additives or processes are given in List II-27, "Warm Mix Asphalt Products and Processes" of the Materials, Sources, and Devices with Special Acceptance Requirements manual. Asphalt Rejuvenators will be accepted on a case by case basis if they improve the performance of the mix as determined by the tests in section (e) of this document

(e) Mix Properties.

Article 424.02(e) shall be replaced by the following:

(e) Mix Properties.

1. Air Voids (Va).

The design air voids for the mix shall be between 1.5% and 6.5%

2. Blank

3. Liquid Asphalt Binder Content (Pb).

The Liquid Asphalt Binder Content (Pb) shall be that given in the submitted mix design which meets the criteria for resistance to rutting and resistance to cracking. Asphalt content shall be within +/- 0.25% of that in the mix design. Blank

4. Liquid Asphalt Binder Draindown.

A fiber stabilizer meeting the requirements given in Section 410 may be incorporated into the mix to reduce draindown. The fiber shall be blended into the mix in accordance with the requirements given in Section 410.

5. Resistance to Moisture-Induced Damage.

All mixes shall be designed and produced to have a tensile strength ratio (TSR) of at least 0.80 when compacted according to ALDOT-384 at 7.0 % air voids and tested in accordance with AASHTO T 283 as modified by ALDOT-361, except the specimen shall be 6.00" {150 mm} in diameter and 3.75" {95 mm} in height.

6. Resistance to Cracking (CT index)

All mixes shall be designed to have a Cracking Tolerance Index (CT Index) as specified in the Target HT-IDT and CT Index table below and tested according to ALDOT 459 Alabama Cracking Test for HMA (AL-CT). CT index testing during production will be for information purposes only.

7. Resistance to Rutting (Hot Indirect Tensile Strength)

All mixes shall be designed to have an average HT-IDT strength as specified in the target HT-IDT and CT Index table below when tested by ALDOT 458 Hot Indirect Tensile Test. HT-IDT testing during production will be for information purposes only.

Target HT-IDT and CT index for Each Test Section		
Test Section	Design HT-IDT	Design CT index
1	14-18 psi Low	55-77 Med
2	14-18 psi Low	83-117 High
3	20-30 psi Med	27-39 Low
4	20-30 psi Med	83-117 High
5	35-45 psi High	27-39 Low
6	35-45 psi High	55-77 Med

8. Friction ratio by Dynamic Friction test (DFT)

All Mixes containing more than 35% recycled asphalt pavement (RAP) shall be tested for friction ratio by testing a comparator mix of proportionally identical design except that the RAP content shall be 35%. Both mixes shall be polished in a Three Wheel Polishing Device and tested for friction according to ASTM E1911 Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester. The DFT number of the high RAP sample shall be at least 94.0% of that of the comparator sample. This test will be for mix design approval only.

424.03 Gradation Requirements.

Article 424.03 shall be replaced by the following:

Production Gradation Tolerances For Trial Sections	
Sieve Size Range	Tolerance (percent retained by mass)
Larger than or equal to No. 8	+/- 7%
No. 16 to No. 100	+/- 4%
No. 200	+/- 2%

APPENDIX B: QC DATA

		Section 1			Section 2		
Sieve	**mm**	**Design**	**Production**	**Delta P-D**	**Design**	**Production**	**Delta P-D**
1-1/2	37.5	100	100.0	0.0	100	100.0	0.0
1	25	100	100.0	0.0	100	100.0	0.0
3/4	19	100	100.0	0.0	100	100.0	0.0
1/2	12.5	99	98.8	-0.2	98	95.9	-2.1
3/8	9.5	90	90.9	0.9	90	88.3	-1.7
#4	4.75	64	63.1	-0.9	62	60.2	-1.8
#8	2.36	44	43.2	-0.8	41.1	40.5	-0.6
#16	1.18	36	34.5	-1.5	33.3	32.6	-0.7
#30	0.6	28.9	25.9	-3.0	26.5	25.1	-1.4
#50	0.3	13.2	12.3	-0.9	12.3	12.9	0.6
#100	0.15	6.3	5.4	-0.9	6.2	6.2	0.0
#200	0.075	4.2	3.4	-0.8	3.9	4.0	0.1
NMAS		9.5	9.5		9.5	9.5	
PCS		2.36	2.36		2.36	2.36	
PCSI		-3	-3.8	-0.8	-5.9	-6.5	-0.6
IDEAL-CT		56.37	68.44	12.1	91.34	93.12	1.8
HT-IDT		15.85	17.17	1.3	15.7	15.21	-0.5
AC%		5.30	5.31	0.0	5.60	5.52	-0.1
VMA		16.2	15.7	-0.5	15.5	14.5	-1.0
Pbe		5.24	5.01	-0.2	5.60	5.40	-0.2

	Section 3			Section 4		
Sieve	**Design**	**Production**	**Delta P-D**	**Design**	**Production**	**Delta P-D**
1-1/2	100	0.0	-100.0	100	100.0	0.0
1	100	0.0	-100.0	100	100.0	0.0
3/4	100	0.0	-100.0	100	100.0	0.0
1/2	100	0.0	-100.0	99	97.8	-1.2
3/8	97	3.0	-94.0	90	89.6	-0.4
#4	75	25.0	-50.0	62	60.8	-1.2
#8	53.2	46.8	-6.4	42.4	40.3	-2.1
#16	43.6	56.4	12.8	35.2	32.8	-2.4
#30	34.5	65.5	31.0	28.1	25.6	-2.5
#50	16.5	83.5	67.0	14.2	13.8	-0.4
#100	8.1	91.9	83.8	7.2	7.0	-0.2
#200	5.3	94.7	89.4	4.7	4.7	0.0
NMAS	9.5	9.5		9.5	9.5	
PCS	2.36	2.36		2.36	2.36	
PCSI	6.2	-0.2	-6.4	-4.6	-6.7	-2.1
IDEAL-CT	38.05	54.68	16.6	86.23	79.99	-6.2
HT-IDT	28.93	21.53	-7.4	21.38	20.85	-0.5
AC%	5.40	5.50	0.1	5.80	5.69	-0.1
VMA	17.7	16.5	-1.2	14.9	14.5	-0.4
Pbe	5.39	5.32	-0.1	5.74	5.63	-0.1

	Section 5			Section 6		
Sieve	**Design**	**Production**	**Delta P-D**	**Design**	**Production**	**Delta P-D**
1-1/2	100	100.0	0.0	100	100.0	0.0
1	100	100.0	0.0	100	100.0	0.0
3/4	100	100.0	0.0	100	100.0	0.0
1/2	99	98.3	-0.7	100	100.0	0.0
3/8	96	95.7	-0.3	97	97.1	0.1
#4	72	72.7	0.7	72	72.5	0.5
#8	48.4	50.8	2.4	48.8	50.9	2.1
#16	38.5	40.7	2.2	38.2	41.0	2.8
#30	30	31.1	1.1	29.7	31.3	1.6
#50	16.3	15.9	-0.4	15.7	16.1	0.4
#100	8.8	7.5	-1.3	8.4	7.9	-0.5
#200	5.9	4.6	-1.3	5.7	5.1	-0.6
NMAS	9.5	9.5		9.5		
PCS	2.36	2.36		2.36		
PCSI	1.4	3.8	2.4	1.8	3.9	2.1
IDEAL-CT	30.93	25.67	-5.3	55	67.46	12.5
HT-IDT	37.03	40.82	3.8	37.4	30.86	-6.5
AC%	5.40	5.52	0.1	5.80	5.78	0.0
VMA	15.5	15.9	0.4	15.5	15.8	0.3
Pbe	5.38	5.28	-0.1	5.78	5.65	-0.1