Division of Construction Research On-Call Services 2020-2023 Task 1: Detection of Segregation in Asphalt Concrete Pavement

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16. Abstract

Segregation in asphalt pavement can manifest either as variation in the gradation of the aggregate in the asphalt mix (gradation segregation) or as variation in the temperature (thermal segregation), and both may occur together. Perhaps the primary cause of segregation is improper handling during mixing, transportation, and placement of the asphalt, which can occur at the silo or at the end of the load or elsewhere in the paving process.

This report includes a literature review, national survey of state DOTs, and review of construction and materials specifications to assess the current state of the practice in mitigating segregation in asphalt pavement. Recommendations for possible implementation are given.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(°F-32)/9 or (°F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2 or psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8°C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2 or psi

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1 Problem statement

The Ohio Department of Transportation (ODOT) Construction Administration Manual of Procedures defines segregation as "The separation of the coarse and fine particles sizes in an aggregate or asphalt mixture" [ODOT, 2017]. Rada et al. [2013] identified segregated mix as the common cause of patching, raveling, and stripping, all of which lead to premature failure of pavement. Currently, ODOT inspectors control segregation by monitoring the asphalt stockpile management and visually observing the asphalt mixture in the haul trucks, paver, and the asphalt mat behind the paver. The inspector's evaluation is subjective and is generally challenged by the contractor, resulting in disputes and possibly financial claims.

When anti-segregation equipment is specified, the specification requirements for segregation detection are less subjective. The contractor must demonstrate temperature differentials of less than 35F° (19C°) during placement of a 1000 ft (305 m) test strip [ODOT, 2017]. However, currently the use of thermal imaging and other methods, such as the rolling density meter, are not common and in the development phase.

Segregation of asphalt layers, especially asphalt base, is not uncommon in Ohio. During construction of the perpetual pavement test section on US 30 in Wayne County, segregation of the asphalt base was visually identified and confirmed by resilient modulus and indirect tension testing in the laboratory. The storage silo was identified as the source of segregation. With the issue resolved, the segregated pavement was removed and replaced [Kim et al., 2010].

Green et al. [2018] conducted an extensive investigation of 51 projects in Ohio constructed with asphalt base to evaluate ODOT's construction and acceptance criteria. Segregation was observed during construction or found in cores for 8 of 51 projects. The investigation also included a review of thirteen state department of transportation (DOT) specifications and one Canadian province specification. Texas and Michigan had specifications which address the detection of segregation during construction. Texas DOT has two specifications for detection of segregation, Tex-207-F and Tex-244-F. Specification Tex-207-F, Part V, provides a procedure to detect segregation based on a density profile determined for a 50 ft (15 m) section using a density gauge. Specification Tex-244-F utilizes a handheld thermal camera or paver mounted thermal system to measure the surface temperature of the asphalt mat directly behind the paver. Thermal segregation is determined by subtracting the measured temperature from the maximum baseline temperature. Michigan DOT Test Method 326 provides a procedure to verify and quantify observed segregation by comparing density as measured with a density gauge in the segregated area to density in an unsegregated area.

2 Research Background

To reduce contractor disputes and claims, and to improve pavement performance, a more objective test procedure is needed. The objective of this task order is to locate available information on better quantitative approaches to measuring segregation, along with successful countermeasures and remedies. The information has been obtained via a survey of state DOTs, an examination of their construction and materials specifications, and a review of the literature, particularly evaluations of innovative technologies. This project particularly focuses on segregation caused by aggregate gradation, rather than thermal segregation, as this was the priority emphasized by the Technical Advisory Committee (TAC) members.

3 Research Approach

These are the steps involved in meeting the objectives.

1. Review Literature on Asphalt Segregation: Extensive literature searches were conducted on detection of segregation in asphalt mixes through web-based queries and specialized search portals.
2. Conduct Survey of Current Practices: A survey questionnaire comprising a set of questions regarding specifications for detecting segregation used by other DOTs and roadway agencies was developed and reviewed extensively by the TAC. Ohio University used the Qualtrics online survey platform to administer the questionnaire. ODOT distributed the survey link to the other state DOTs through the AASHTO RAC listserv.

3. Follow up on Survey Responses and Document Leads. The research team searched the internet for each state DOT's Construction and Material Specifications (C&MS), supplemental specifications, and special provisions. These specifications and provisions were searched for mentions of segregation in asphalt concrete. Those state DOTs with specifications for detecting segregation, such as Texas DOT and Michigan DOT, were to be contacted to obtain further details on the effectiveness of the test methods, cost of implementation, and software, if any.
4. Generate Report. Results from Steps 1-3 have been combined together in this report summarizing all findings, comparing segregation detection test methods, and identifying which may be worth investigating for potential implementation.

3.1 Literature Review

3.1.1 NCHRP Report 441

Mary Stroup-Gardiner co-authored two key NCHRP reports on segregation. The first is NCHRP Report 441, co-authored with E.R. Brown in 2000 and entitled *Segregation in Hot-Mix Asphalt Pavements* [Stroup-Gardiner and Brown, 2000]; the other is NCHRP Synthesis 477, published in 2015 and entitled *Methods and Practices on Reduction and Elimination of Asphalt Mix Segregation* [Stroup-Gardiner, 2015].

NCHRP Report 441 [Stroup-Gardiner and Brown, 2000] presents an overview of practice related to detecting, measuring, and remediating asphalt concrete (AC) segregation. Stroup-Gardiner and Brown investigated several technologies with potential for detecting segregation: Thermal imaging (infrared radiation (IR) imaging), Ground-Penetrating Radar (GPR, based on permittivity), Thin-lift nuclear density/asphalt content gauge, Laser surface texture measurements, and Seismic Pavement Analyzer (SPA). They also conducted a survey of then current practice in the USA and abroad, as well as a field and laboratory study and an investigation of the cost of segregation to transportation agencies.

The NCHRP report includes the following definitions for four levels of segregation ranging from no segregation to high-level segregation [Stroup-Gardiner and Brown, 2000, p. 2-3]:

- *Areas with **no segregation**, assuming that proper mix design and compaction is attained, will have acceptable air voids, greater than 90 percent of the anticipated mix stiffness. The asphalt content will be within 0.3 percent of the job mix formula, and there will be no statistical difference in the percent passing any of the coarse sieve sizes.*
- *Areas with **low-level segregation** will have a mix stiffness of between roughly 70 and 90 percent of the nonsegregated areas and increased air voids of between 0 and about 4 percent. If gradation segregation is present, at least one sieve size will be at least 5 percent coarser and there will be a corresponding decrease in asphalt content between 0.3 and 0.75 percent.*
- *Areas with **medium-level segregation** will have a mix stiffness of between about 30 and 70 percent of the nonsegregated areas and increased air voids of between 2 and 6 percent. If gradation segregation is present, at least two sieve sizes will be at least 10 percent coarser and there will be a corresponding decreased asphalt contents between 0.75 and 1.3 percent.*
- *Areas with **high-level segregation** will have a mix stiffness of less than 30 percent of the nonsegregated areas and increased air voids of more than 4 percent. If gradation segregation is present, at least three sieve sizes will be at least 15 percent coarser and there will be a corresponding decreased asphalt content of greater than 1.3 percent. Cores will have a tendency to fall apart upon coring or cutting.*

NCHRP Report 441 also includes a summary table of the effect of segregation level on AC mixture properties, reproduced in Table 1. Segregation can reduce the resilient and dynamic moduli by as much as half, and tensile strength can be reduced to as little as 30% of the non-segregated value. Fatigue life can be reduced by as much as 99% when there is high level segregation.

Table 1. Summary of the influence of segregation on mixture properties. [Stroup-Gardiner and Brown, 2000, Table S-1, p. 2]

Mixture Property	Percent of Non-Segregated Mix Property by Level of Segregation			
	Fine	Low	Medium	High
Permeability	Increased slightly	Increasing with level of coarse segregation		
Resilient Modulus	Little or slightly increasing stiffness	80 to 90%	70 to 80%	50 to 70%
Dynamic Modulus	Little or slightly increasing stiffness	80 to 90%	70 to 80%	50 to 70%
Dry Tensile Strength	110%	90 to 100%	50 to 80%	30 to 50%
Wet Tensile Strength	80 to 90%	75%	50%	30%
Low-Temperature Tensile Stress	No conclusions due to test method difficulties			
Loss of Fatigue Life when Segregation in Upper Lifts, %	Not Estimated	38%	80%	99%
Rutting Potential	Not strongly influenced by gradation segregation			Mixed Results

Stroup-Gardiner and Brown focused on evaluating three promising technologies: density on the run (DOR) nuclear gauge, Infrared thermography, and ROSAN-V surface texture measurements, and recommend the latter two, including an example specification and a proposed draft AASHTO provisional standard for each. The example specification and proposed draft provisional standard test method for the ROSAN-V method are reproduced in Appendix A. Both example specifications include the definitions of low, medium, and high level segregation, and define two types of segregation, temperature and gradation [Stroup-Gardiner and Brown, 2000, p. 85, 87].

Temperature segregation*: refers to portions of the mix with significantly different temperatures. This type of segregation can occur as the result of the surface of the mix cooling in the haul truck, cold mix in the paver wings getting raised immediately prior to the addition of fresh hot mix, and any anomalies in the paving operations that result in areas with significantly different temperatures.*

Gradation segregation*: is the separation of the coarse and fine aggregate fractions.*

Sieves*: Gradation results are based on using the following sieves in the analysis: 37.5, 25, 19, 12.5, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.072 mm.* [1.5, 1, ¾, ½, $^3/_8$ in, #4, #8, #16, #30, #50, #100, #200]

For thermal segregation, detection is based on the temperature difference between two areas, either transversely adjacent patches in typical end-of-paver segregated areas or in longitudinally adjacent areas 50 ft (15 m) long in typical behind-paver low-density areas. Segregated areas are cooler and the level of segregation is based on criteria in Table 2.

Table 2. Identification of a discrete segregated area using infrared thermography. [adapted from Stroup-Gardiner and Brown, 2000, p. 85].

No Segregation	**Low-Level Segregation**	**Medium-Level Segregation**	**High-Level Segregation**
Area in the mat with temperatures of 10°C (18°F) or less of a difference between coldest and hottest temperatures	A discrete area in the mat with a mean temperature between 11 and 16°C (20° and 29°F) cooler than the surrounding area	A discrete area in the mat with a mean temperature between 17 and 21°C (30° and 38°F) cooler than the surrounding area	A discrete area in the mat with a mean temperature more than 21°C (38°F) cooler than the surrounding area

For gradation segregation, detection is based on ROSAN-V surface texture measurements, expressed as multiples of the estimated texture depth (ETD) as defined in ASTM E1845, which is the equivalent of the ETD in the sand patch test (ASTM E 965). The criteria for the various levels of segregation (no, low, medium, and high segregation) are given in Table 3. To measure segregation, a lot of AC pavement, defined as 5000 lane-ft (1500 lane-m), is divided into ten equal length sublots, of which three are selected for testing. Testing consists of longitudinal ROSAN-V mean profile depth (MPD) measurements taken along paths at W/3 and 2W/3 for lane width W < 12 ft (3.6 m) or at W/4, W/2, and 3W/4 for W ≥ 12 ft (3.6 m). The percent segregation of a particular level is defined as the fraction of data points within segregation limits times 100, including all two or three longitudinal paths in the sublot. These percentages are averaged to get a segregation percentage for the entire lot. The levels of segregation are defined by multiples of the ETD given in Table 3, and the ETD of non-segregated pavement itself is computed using the maximum aggregate size (A), percent passing the 4.75 mm (#4) (A_4) sieve, coefficient of curvature (C_c), and coefficient of uniformity (C_u) using the equation given in the example specification and draft AASHTO provisional standard [adapted from Stroup-Gardiner and Brown, 2000, p. 88, 95]:

$$ETD = 0.01980\ (A) - 0.004984\ (A_4) + 0.1038(C_c) - 0.004861(C_u)$$

Table 3. Identification of a discrete segregated area using ROSAN-V surface texture measurements as multiples of the estimated texture depth (ETD). [adapted from Stroup-Gardiner and Brown, 2000, p. 88].

Limit	No Segregation	Low-Level Segregation	Medium-Level Segregation	High-Level Segregation
Lower (ETD)	0	1.16	1.57	> 2.09
Upper (ETD)	1.15	1.56	2.09	None

There was great optimism for the ROSAN-V system, as evidenced by an FHWA Technical Note [Sixbey, 1997]. Since then, interest has waned and the provisional standard and example specification appear to not have been adopted, and better technology has been developed.

3.1.2 NCHRP Synthesis 477

Perhaps the most comprehensive document on segregation in asphalt concrete pavement is the recent NCHRP Synthesis 477 by Mary Stroup-Gardiner [2015]. Stroup-Gardiner identified three types of segregation that produced texture variations in AC pavements: random, longitudinal, and end of truck load. She found that segregation was more likely when the aggregate was larger. In particular, AC mixes with aggregate smaller than 3/8 in (9.5 mm) rarely segregated, while segregation was likely in dense mixes with maximum aggregate size 1.5 in (37 mm) or larger. In addition, insufficient binder in the mix was also likely to produce segregation. However, in the conclusions, Stroup-Gardiner noted: *Standard definitions and descriptions for all types of segregation were not consistently defined. Such descriptions and terms can help improve consistency when visual detection is the standard detection method.*

Segregation can be detected and measured in several ways: By visual observation of surface irregularities (nearly universal use); via temperature differences (e.g. with infrared camera or non-contact thermometer; second most prevalent, used by about 20% of agencies); by measuring surface texture (e.g. ride quality, photographic image analysis, or static measurements such as sand patch test or Circular Track (CT) Meter); or by measuring density variations (e.g. ground penetrating radar (GPR), nuclear gauge, or intelligent compaction). Aggregate segregation in asphalt may be detected by thermal means if the differences in temperature are due to the differences in the aggregate composition in areas being compared, but the other means are more direct. There are several methods to detect density variations in asphalt. The most common is to collect core specimens and analyze them in the laboratory, which is destructive and introduces a delay. Faster alternatives include ground penetrating radar (GPR), which measures permittivity of the pavement, nuclear density gauge, non-nuclear density gauge (typically also based on permittivity), or an intelligent compaction roller. In place performance-based testing is not frequently used to evaluate rutting, fatigue, tensile strength, or permeability of segregated mix.

Stroup-Gardiner [2015] also stresses the importance of a training and certification program to minimize the presence of segregation in pavements. In particular, there needs to be a consistent understanding on the definition of segregation, methods of detection, causes, and remediation approaches. She also notes that there is a “wide mix of agency staff and consultants” engaged in field inspection efforts to detect segregation. Standard definitions or descriptions of segregation and a shared understanding of the problem are necessary for everyone involved to minimize disputes and conflicts. Stroup-Gardiner lists three remedies (“disincentives”) used for segregation problems. Most common is “remove and replace”. Construction delays caused by additional testing are also noted as a “good disincentive”. However, percent within limits and incremental pay factors were not frequently used. She recommends these changes for specifications: reduced subjectivity, more use of temperature measurements, mandating core collection, and setting smaller tolerances for QA/QC testing. Regarding field testing, Stroup-Gardiner observes that the method of using nuclear and non-nuclear density gauges is not consistent, for example in the type of profile or sampling used to collect data points. Nuclear density gauges will overestimate density on coarse surfaces, while non-nuclear gauges are sensitive to changes in moisture content. For laboratory testing, it is noted that the AASHTO T166 method overestimates density in segregated specimens because they are more permeable. The conclusions of the synthesis include four tables [Table 30 through Table 33 in Stroup-Gardiner, 2015, p. 70-73]) describing many locations in the asphalt manufacturing and placement processes where segregation can be reduced during mix design, aggregate production, at the asphalt plant, during mix transport and transfer, and at the paver. Such precautions serve as a checklist for tracing possible causes of segregation, which are used in some states.

3.1.3 Laser profiling devices

McGhee and Flintsch [2003] followed up on NCHRP Report 441 [Stroup-Gardiner and Brown, 2000] by performing a comparison of several pavement texture measurement systems on various sections of the Virginia Smart Road and at NASA's Wallops airport. The Virginia Smart Road included 5 Superpave® mixes, 12.5 mm and 19 mm stone mastic asphalt (SMA) and 12.5 mm maximum nominal aggregate size open-graded friction curse (OGFC). The Wallops airport included grooved and non-grooved small-aggregate HMA, rejuvenated AC with and without sand, some MS/0 mixes with overlays (slurry seal, anti-skid, and single and double overlays of microsurfacing). The methods tested included the Circular Track (CT) Meter (following ASTM Standard E2157), the sand patch test (following ASTM Standard E965), the International Cybernetics Corporation (ICC) and MGPS high-speed texture measuring systems. The MGPS system represents an evolution of the ROSAN project and presents a mean profile depth (MPD) following ASTM E1845 [McGhee, Flintsch, and Izeppi, 2003, p. 2]. The MGPS uses a higher frequency (64 MHz) laser than the ICC, which enables higher definition profiles.

The McGhee and Flintsch [2003] comparison of the CT Meter and the sand patch test found remarkable agreement, stating "For all practical purposes, the output from the two static texture-measuring techniques is equivalent." ORITE's own experiences with the CT Meter and sand patch test on research projects in the field has shown the CT Meter reduces the time needed to take a measurement by a factor of 3, from about 15 minutes down to 5 minutes [Issam Khoury and Joshua Jordan, personal communication, June 23, 2021]. McGhee and Flintsch further recommend using the CT Meter to collect some "ground truth" measurements for comparison/calibration with other methods. They also recommend the ICC system for AC surfaces, despite the ICC system results being consistently about 50% larger than the MGPS MPD values. McGhee and Flintsch noted the "very best agreement was between the MGPS system and the CTM" as both output MPD results, but all comparisons had high correlations.

Hanson and Prowell [2004] did a similar comparative study of MPD measurements made by sand patch test and CT Meter using 45 sections on the NCAT Test Track, including coarse and fine Superpave mixes, open graded friction course (OGFC), Hveem mixes, stone mastic asphalt (SMA), and Novachip. The differences between the CT Meter and sand patch results were not significant when OGFC sections were excluded. They recommended using the average of two CT Meter readings and noted that less technician skill is required to use the CT Meter than to perform the sand patch test.

Subsequent reports by McGhee, Flintsch, and Izeppi [2003] and McGhee [2005] shifted emphasis from identifying segregation to measuring ride quality and uniformity. In essence McGhee, Flintsch, and Izeppi [2003] proposed discouraging segregation by establishing limits on allowable fluctuation of pavement macrotexture, or as it was put by McGhee [2005, p. i]: "Rather than emphasize segregation detection and measurement, the proposed special provision promoted new-surface uniformity." However, the 2005 study revisited the proposed special provision and said a "texture-based 'segregation specification'" was not specifically supported; more study of the problem was recommended along with further evaluation of the high-speed texture measuring system once it was delivered. Other recommendations included using smaller aggregate Superpave mixtures ($^3/_8$ in (9.5 mm) vs ½ in (12.5 mm) maximum size). McGhee also provided a cost-benefit analysis suggesting the additional $900 per lane-mile ($560 per lane-km) for using a material transfer vehicle (MTV) during paving operations would save $3000 of loss of service over the life of the pavement.

However, within a couple years, McGhee and his coauthors [Hughes, McGhee, and Maupin, 2007] conceded a working end-result specification for HMA would "take several years and many steps to achieve", of which this new report represented just the "next step" in the process. Statistical quality assurance specifications for AC material and AC pavement were developed and evaluated by applying to a sample of VDOT resurfacing projects as a "'shadow' application" while the projects were actually accepted according to pre-existing specifications. They also note adopting end-result specifications may allow up to $2 million in annual savings in reduced demand for inspector labor. However, the report recommendations include collecting and analyzing more data and partnering for further study to revise the special provisions. Thus by 2007, in Virginia at least, the use of ROSAN/MGPS to identify segregation had morphed into identifying “statistical quality assurance” criteria for specifications.

More recent iterations of laser profiling technology have focused primarily on collecting inventory and pavement condition data such as international roughness index for pavement management systems, rather than on directly checking particular spots of pavement for segregation, reflecting a change of interest in how the technologies are used. Examples include the PathRunner multisubsystem van [Pathway Services, Inc., 2021] and the Automatic Road Analyzer (ARAN) vehicle [Fugro Roadware, 2014], which include multiple laser scan devices to monitor surface texture (IRI) and rut depth (Laser Rut Measuring System (LRMS)) along with asset photographs collected from front, rear, left, and right cameras, all tied to location data from GPS and DMI. Rowe et al [2002, 2002a] used ARAN to develop an AREA index for acceptance or non-acceptance implemented by the “NJTxtr” software program developed for the New Jersey DOT.

3.1.4 Image analysis

The other legacy of ROSAN-V and successor approaches is ongoing work on using image processing technology to identify segregation, for example as in work by Baqersad et al [2017], who analyzed greyscale images of pavement from which a histogram of intensity could be derived. Baqersad and colleagues found the histograms (generated by MATLAB code) from images of segregated pavement had significantly higher standard deviations than those from nonsegregated pavement after processing and sorting using a linear discriminate analysis (LDA) technique using SPSS software. The potential segregated areas were verified by visual inspection by engineers. The approach was tested on two projects in Florida paved with a 9.5 mm ($^3/_8$ in) FC9.5 Superpave surface. They suggest this method could help resolve disputes between contractors and agencies with over 80% accuracy. The research does not go so far as to propose a standard or specification, and further development would be needed to extend the approach to other AC mixes. Image-based methods of this sort are still in development and not ready for deployment. Other possible issues would include ensuring consistency of image quality by ensuring similar lighting conditions and distance from pavement, etc. The Baqersad et al [2017, p. 3] study approached this issue by having the same person take all the pavement images using the same camera through a hole cut in a short end table to ensure the distance to the pavement surface was uniform.

The next year, Baqersad et al [2018] examined the validity of the Florida Texture Meter (FTM) to measure the mean profile depth (MPD) of gradation segregated, thermally segregated, and non-segregated patches of pavement on eleven recently constructed road sections in Florida. Results were classified using the 2-sigma method. The process involves splitting a project into 25 sections, with 20 visually identified as non-segregated and the rest as segregated. The threshold criterion for segregation is based on the standard deviation (σ) of the FTM measurements of the non-segregated sections. For the remaining 5 segregated areas, if the FTM measurement lies outside the range 2σ above and below the non-segregated mean, then the FTM measurement validates the segregated designation at a 95% confidence level. While the odds of a false positive (nonsegregated are designated segregated) are 5%, the false negative rate (segregated pavement not identified because they are within the 2σ limit) may be higher. Additionally, this method relies on making a visual identification first and then making (possibly) confirming measurements.

Cong et al [2019] proposed a segregation detection method based on using a machine learning classifier trained with 224 images of pavements with different levels of segregation and identifying 14 texture features (e.g. contrast) of segregated areas. A principal content analysis was used to extract 6 major identifying components which were fed into a naïve Bayesian classifier able to classify the original images with 87.5% accuracy, which means on average one in every eight would be misclassified.

Zhao, Xue, and Xu [2021] looked at combining two traditional image processing algorithms, the local binary pattern (LBP) and the gray-level co-occurrence matrix (GLCM) to create an LBP-GCLM method combined with a support vector machine (SVM). After validation against a variety of textures from a standard set (The Kylbury texture dataset), the authors claim a 94% accuracy of diagnosis; however the data set consisted of images of a variety of non-asphalt textures – scarf, rice, blanket, and stone.

Overall, the diversity of approaches used by Baqersad et al [2017, 2018], Cong et al [2019], and Zhao, Xue, and Xu [2021] make it evident there is no consensus on how to process and use image data to rapidly detect segregated AC pavement. Research in the area is ongoing as imaging technology and analysis algorithms undergo continuous development.

3.1.5 Segregation on SHRP Test Road DEL-23

A forensic study on the Ohio SHRP Test Road on US Route 23 in Delaware County was conducted after six years of service after opening in 1996 on AC Sections 390103, 390108, 390109, and 390110, which appeared to have undergone localized or imminent distress [Sargand et al., 2006]. Non-destructive and destructive tests were conducted, including distress surveys following the LTPP distress identification manual, falling weight deflectometer, transverse profiling, and dynamic cone penetration tests. Core specimens were collected and studied in the laboratory. Longitudinal top-down surface cracking at the center and in both wheel paths was seen in all four sections, as shown in Figure 1. An examination of cores collected from the pavement found the cracks were generally limited to the top four inches (100 mm), and were similar to longitudinal cracking in Colorado attributed to segregation [Harmelink and Aschenbrener, 2003]. Regarding this cracking, the report concluded:

The longitudinal cracking observed in all test sections was the result of the segregation of aggregates in the asphalt mix at the time of construction, the augers or spreaders in the paving machine are the most likely cause of the segregation of aggregates. This segregation is reflected in the much higher percentage of air voids seen in the core samples taken for the forensic study compared to those recorded at the time of construction. [Sargand et al, 2006]

Figure 1. Longitudinal surface cracks in DEL-23 SHRP Test Road sections 390108, 390109, and 390110 [Sargand et al., 2006].

Figure 2. Close-up of longitudinal surface crack in DEL-23 SHRP Test Road, with white line added indicating where segregation was observed in the specimen [Sargand et al., 2006].

3.1.6 Segregation on WAY-30

Another major ODOT test pavement was built on the US Route 30 bypass around Wooster in Wayne County, also called WAY-30, and opened to traffic in December 2005. Construction of asphalt base course at the instrumented section was halted due to segregation, which can be seen in Figure 3. The visually identified segregated section was reported and later confirmed by resilient modulus and indirect tensile strength tests in the laboratory. The resilient modulus in the segregated pavement was clearly lower than the non-segregated pavement, as can be seen in Figure 4. The contractor identified the storage silo as the source of the segregation. They fixed the problem immediately and the segregated pavement was removed and replaced [Kim, Sargand, Masada, and Hernandez, 2010].

Figure 3. Segregation observed in asphalt base course on WAY 30 [Sargand, 2006, slides 30-31].

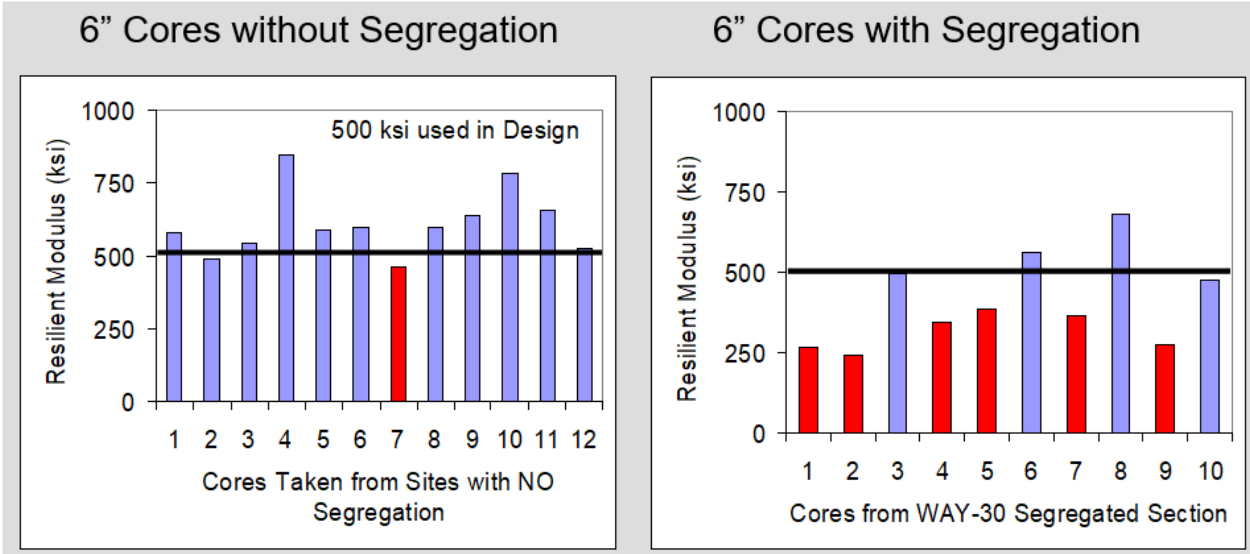


Figure 4. Resilient modulus test results on asphalt base course placed on WAY-30 on right are non-segregated sections and on the left are segregated sections [Sargand, 2006, slide 33]. (6" = 150 mm, 1 ksi = 6.89 MPa).

3.1.7 Asphalt Base Course Construction and Acceptance Requirements

A report entitled *Evaluation of Asphalt Base Course Construction and Acceptance Requirements* [Green et al., 2003] included a survey of state specifications on AC base courses, and found many specify density testing of AC base layers. Texas DOT had a maximum allowable density range of 8.0 lb/ft^3 (128 kg/m^3) maximum to minimum or 5.0 lb/ft^3 (80 kg/m^3) mean to minimum. Pennsylvania DOT required the mat density between 0.89 and 1.00 times the maximum theoretical density. In addition, the report noted the standards Texas and Michigan DOTs had for segregation. In Michigan, the mat must be removed and replaced if the segregated area exceeds 215 ft^2 (30 m^2) or 328 ft (100 m) lane length. Texas DOT mandated an infrared (IR) scanner mounted on the paver for thermal imaging across the entire width. Per Texas Test Procedure 244-F, temperatures are monitored every 150 ft (46 m), and thermal segregation is defined as follows: Minimal: 0-25 F° (0-14 C°); Moderate: 25-50 F° (14-28 C°); Severe: >50F° (>28C°). Data are sent for review by the DOT and identification of potential segregation areas for possible follow-up density measurements.

Green et al. [2003] also collected 720 AC base layer core specimens from 51 pavement projects across Ohio. The cores were tested to determine cracking potential, moisture susceptibility, durability, and density and compared to available job mix formula (JMF) data. Seven of the 51 projects (13.7%) had segregation detected in the cores or observed during construction. The report also found that three of the segregated projects had cores with high Cantabro mass loss (> 30%), low tensile strength ratio, TSR (0.51 or less), and high average in-place air content (> 7%), and all of these projects were designed based on Supplemental Specification 880. Because of the observed segregation, the report recommended a second phase to investigate methods to identify segregation during paving along with monitoring of temperature at time of delivery and during compaction. Further research was recommended to determine if Cantabro mass loss testing is a viable tool for verifying segregation in AC pavements and a threshold mass loss value indicating segregation. In the proposed second phase, segregation was to be evaluated via TXDOT methods Tex-207-F Part V and Tex-244-F and Michigan DOT Standard Specification for Construction Section 501. A proposed second phase of the project was not performed.

3.1.8 Review of Non-nuclear Density Gauges

Sargand, Kim, and Farrington [2005] reviewed the performance of two non-nuclear gauges, the PaveTracker™ and the PQI Model 300, for measuring the in-place density of asphalt pavement as an alternative to nuclear gauges. Both devices operate by measuring the dielectric permittivity of the asphalt concrete, which is then used to determine the air void content. The PaveTracker™ was studied in the laboratory under a variety of conditions, including size of aggregate, specimen depth and area, and presence of moisture. Both devices were tested in the field at 24 project sites and compared to measurements made with a nuclear gauge and from laboratory analysis of core specimens. The field results were used to find correlations and make statistical analyses. The statistical analysis found that the pavement quality indicator (PQI) Model 300, when properly calibrated at the beginning of each day, would provide results in agreement with the nuclear gauge and core specimen measurements. In fact, the calibrated PQI measurements agreed better with the core measurements than did the nuclear gauge. Consequently, the PQI Model 300, when properly calibrated daily according to manufacturer's specifications by applying a mix-specific offset, was recommended as a viable alternative to the nuclear gauge for quality control (QC) and quality (QA) testing. The PaveTracker™ did not provide such agreement, though it may have value as a QC device for contractors. The report further notes that density was adopted a proxy for pavement stiffness, and improvements in equipment have made it possible to develop a means of directly measuring stiffness in the field, which should be investigated.

3.1.9 ODOT Reviews of Thermal Imaging Systems and Rolling Density Gauges

Landefeld evaluated the Pave-IR thermal imaging system for ODOT's Office of Construction Administration [Landefeld, 2014]. The study objective was to see what temperature differential readings would be acquired with various equipment setups and paving methods, how the density correlated with temperature variations, and whether the device could detect segregated pavement. To meet objectives, the Pave-IR was used to collect 150 ft (46 m) long profiles which were compared to density measured with a nuclear gauge every 10 ft (3 m) and correlated to core specimen results on 6 paving projects in 2012 and 2013. The paving projects included the use of MTDs, remix devices, and standard truck end dump paving methods. Landefeld found the remix devices had the least temperature variation, while the end dump approach had the most variation. Landefeld also concluded that while thermal segregation did not always correlate with density, thermal control did help reduce density deviations. It was also found that acceptance cores collected via ODOT Item 446 were not sufficient to find isolated low density spots, which could be 20 ft (6 m) or less in length. The report then recommended continuing to collect thermal and density data on AC paving projects to further populate ODOT's database. Material transfer devices (MTDs) and remixers did improve pavement uniformity, though were not a cure-all for all segregation issues.

Landefeld [2020] evaluated the rolling density meter (RDM), comparing results to those from the thermal profiler. The RDM provides the advantages of fast results, non-destructive testing, and nearly full coverage of the pavement area (over three orders of magnitude greater than coring in terms of the fraction of paved area measured (17% vs. 0.004%)). Landefeld observed the RDM could provide accurate density measurements at much higher sample rates and in real time. He mentioned there is a pooled fund study (TPF-5(443) in progress to further evaluate the precision and bias of the device as well as the effects of moisture and mix adjustments. The presentation also included coverage of the 2014 report on paver mounted thermal profilers (PMTPs), and noted both PMTP and RDM data could be superimposed on Google Maps overhead views of pavement, as shown in Figure 5.

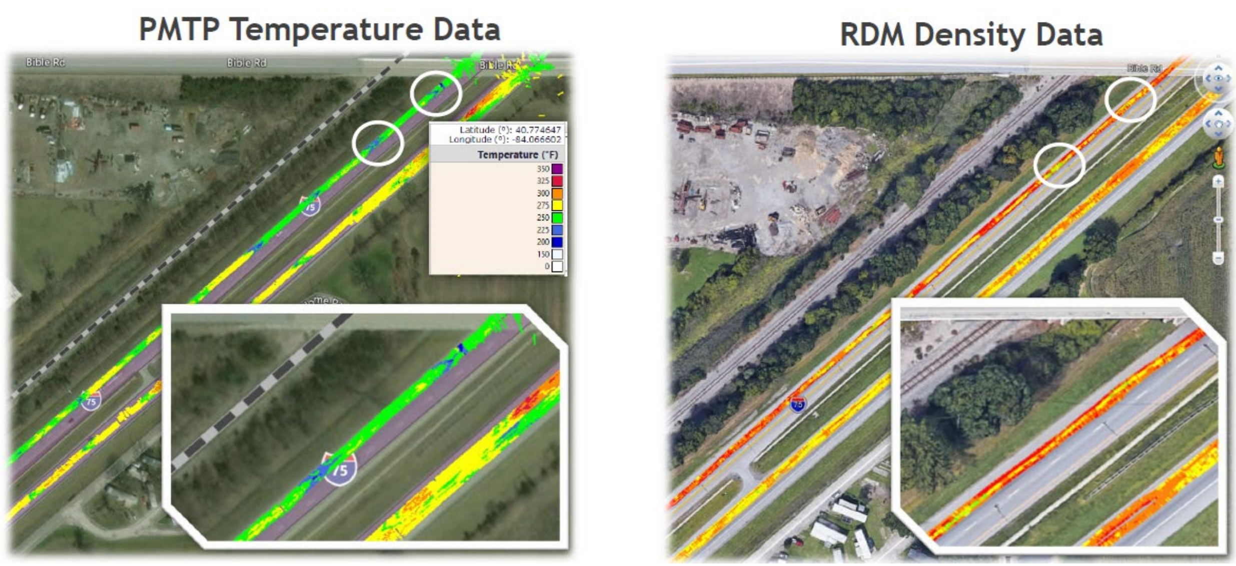


Figure 5. PMTP thermal measurements (left) and RDM density measurements (right) superimposed on Google Maps image of Interstate 75 in Ohio [Landefeld, 2020].

According to the project web site for Pooled Fund Study TPF-5(443) [TPF, 2021], several states have evaluated the RDM with promising results. The pooled fund agencies aim to further develop and improve the system for QA purposes and also provide some training and promotion. One proposed advancement is to incorporate a warning for data collecting system errors. Another objective is to develop AASHTO standards for the equipment and data collection/analysis method and operator certifications [TPF, 2021].

3.2 Survey of Current Practices

A survey on AC segregation was developed by the research team in collaboration with the TAC. After several iterations and testing via the survey interface, the finalized survey was administered using Ohio University's Qualtrics account. It was sent by ODOT via the AASHTO RAC listserv to representatives of all US States and Territorial Departments of Transportation (DOTs) and to the provincial transportation ministries in Canada. The survey was answered by 35 DOTs from 34 American states (ME, ID, AL, IL, OK, NC, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, WA, SD, VT, KS, NV, SC, FL, CA, KY, NY, IN) and one Canadian province (SK – Saskatchewan). Two states (NC, ME) completed only about 45% of the questionnaire; the other responses were complete according to Qualtrics. Complete details on who responded and a full set of responses are provided in Appendix B. Selected questions and responses are highlighted below. In addition, many responses from a total of 24 states (68.57% of 35) included references to specifications and other documents (e.g. test methods), though these were not always informative or relevant, and in the case of Saskatchewan reference was made to an as-yet unpublished manual. States that included a relevant reference are indicated with an asterisk (*) below. These specifications and other documents are listed in alphabetical order by state or province in Appendix C, which also includes items from states not responding to the survey.

Several questions (8, 10, 16, 19) allowed recipients to choose more than one response. In Appendix B, Qualtrics computed percentages based on the number of responses. Since this project is looking for the prevalence of various practices among states, percentages have also been calculated based on the number of respondents (35), both in Appendix B and in the text below in this chapter. As a consequence, the latter percentages will add up to more than 100%. For example, in Question 8 there were 66 responses, and the total percentages based on 35 respondents add up to 194.29% because of the multiple choices selected by responding agencies.

Many other questions were answered in writing (9, 11, 12, 13, 14, 15, 18, 20), and these responses were parsed for commonalities, and where relevant, percentages of the 35 respondents were computed. For example, 5 of 35 respondents (14.29%) to Question 12 mentioned the nuclear density gauge as a field test to measure segregation. These percentages will not add up to 100%, in part because states could mention more than one field test, and in part because not all responses are highlighted in the text.

3.2.1 Definition of Segregation

The first set of questions asked for basic contact information, job title, agency, and state/province. The first question directly on segregation was Question 7: "How does your organization define segregation in AC pavement in its construction and materials specifications?" All states except Kentucky gave a response, but only 16 (45.71% of 35 responses) provided a definition or a link. Overall, there was no consistent or standard definition given. Indeed, the most common response was along the lines of "we don't" (MT) or "not officially defined" (TX); the second most prominent answer was along the lines of "separation of coarse aggregate particles" (MD) or "visual inspection; density variations" (LA). Responses generally clustered in the following categories (an asterisk (*) indicates a state that provided a relevant document reference, such as a specification number):

- Not explicitly defined (13, 37.14%): ME, ID, TN, VA, MT, AZ, TX, WI, MO (survey response), NJ, VT, NY, IN (respondent goes on to mention separation of aggregates)
- Separation/non-uniform distribution of aggregate particles (not specified otherwise, or "bad enough that we can see it" (UT)) (9, 25.71%): MD, AK*, AR, UT, SD, SC*, FL, LA, IN (in elaborating response after saying not defined)
- Quantified binder content difference between cores (1 state, 2.86%): AL
- Quantified gradation analysis between cores or differences from Job Mix Formula (2, 5.71%): AL, PA*
- Quantified density variation (e.g. nuclear gauge) (3, 8.57%): MO* (TM-75), WA*, KS
- Ordinal scale of severity (e.g. Low, Medium, High) (2, 5.71%): IL, SK*
- Vague answers (3, 8.57%): NC, LA, CA

- NA (2, 5.71%): OK, NV
- Visual and thermal (2, 5.71%): CO, NC
- PMTP (1, 2.86%): MN*
- Blank response (1, 2.86%): KY

Some of these responses merit discussion in more detail. Here is the full response from Alabama: *Unacceptable segregation of a hot and warm mix asphalt mat is defined as any area in which two six inch {150 mm} cores are taken and the average percent liquid asphalt binder content of the cores have an absolute difference greater than 0.50 percentage points of the design liquid asphalt binder content, or the combined gradation analysis of the two cores on selected sieves has an absolute difference greater than 10 percentage points from the job mix formula.* From test specification ALDOT 389-98 "Evaluation of Segregated Areas in Hot-Mix Asphalt Pavement" [ALDOT, 2009], the design liquid binder content is in the job mix formula (JMF). The gradation is also compared to the JMF value. Two sieve sizes are generally used, and which sizes depends on the maximum aggregate size following ALDOT's Table I [ALDOT, 2009], shown here in Table 4.

Table 4. Sieve sizes used to evaluate segregation for given maximum aggregate size in Alabama (Table I from ALDOT-389-98 [ALDOT, 2009]).

Determination of Sieves Utilized In Segregation Evaluation	
Maximum Size Aggregate	**Sieves Utilized**
1.5 in (37.5 mm)	½ in and No. 4 (12.5 mm and 4.75 mm)
1.0 in (25.0 mm)	3/8 in and No. 4 (9.5 mm and 4.75 mm)
¾ in (19.0 mm)	No. 4 and No. 8 (4.75 mm and 2.36 mm)
½ in (12.5 mm)	No. 8 (2.36 mm)
3/8 in (9.5 mm)	No. 8(2.36 mm)

* with up to 5% retained on the ½" {12.5 mm}

Pennsylvania's response was *Pattern Segregation. Pattern segregation is continuous or repeated areas of non-uniform distribution of coarse and fine aggregate particles in the finished mat. See current PennDOT Publication 408, Specifications, Section 413.3(h)3. Pattern Segregation ([URL excised for brevity]). The Pub. 408, Specifications also addresses Flushing. See link and Section 413.3(h)4. Flushing.* The first sentence of the response is quoting the first sentence of Section 413.3(h)3. Subsection a "Evaluating Pattern Segregation" says that "If the Representative observes pattern segregation that may result in defective pavement", the contractor will be notified, paving may continue at the contractor's own risk, and a pavement surface macrotexture test (Pennsylvania Test Method (PTM) 751) will be conducted. PTM 751 is essentially a sand patch test, and the text of that method can be found in Appendix C. Specification Subsection 413.3(h)3a then states "The pattern segregation is unacceptable if the difference in average texture depth between non-segregated and segregated areas exceeds 0.024 inch" (0.61 mm). If the pavement is unacceptably segregated, Subsection 413.3(h)3b "Test Section" says paving work will be suspended while the cause of the problem is determined and a corrective action proposed. A test section (not exceeding 200 tons) will be placed to verify the corrective action works before authorizing resumption of paving. Subsection 413.3(h)3c "Defective Pavement" requires the drilling of at least three 6 in (150 mm) cores from both the segregated area and a non-segregated area at specific locations selected by the project's Inspector. These cores will be subjected to tests to "Determine the maximum theoretical density according to Bulletin 27, the core density according to PTM No. 715, and asphalt content according to PTM No. 757 if previously identified problematic aggregates are used in the mixture, PTM No. 702 modified Method D, and PTM No. 739 or other test method identified in the producer QC Plan." Pavement is defective if "the summation of absolute deviations from any two sieves is 20% or more from the JMF, the core density is defective, the mixture is defective in asphalt content, or the mixture is defective for percent passing the 75 µm (No. 200) sieve." The remedy for defective pavement is to remove and replace the full width of the lane from the segregated area plus 5 ft (1.5 m) on either side. Section 413.3(h)4 "Flushing" defines flushing as "continuous or repeated areas of excessive asphalt on the pavement surface". The condition is evaluated following PTM 751, and an area is flushed if the average texture depth is less than or equal to 0.006 in (0.15 mm). Flushed areas are subject to similar remedies – suspending work until a corrective action is proposed, place a test section to verify the corrective action works, and remove and replace the flushed area across the full lane width and length plus 5 ft (1.5 m).

Three states mentioned density variation criteria: Missouri, Washington, and Kansas. Missouri's response to Question 7 indicated there was no official definition in the specifications, but is defined in another document, the Engineering Policy Guide. The verbatim response was *The term 'segregation' is used throughout MoDOT's specifications, typically referring to the segregation of aggregates for use in concrete, asphalt, aggregate base, rock blanket or linings, and even in rock fill applications, but without official definition. Our Engineering Policy Guide (EPG) defines segregation in an asphalt mix as follows: Segregation is the separation of the aggregate in the mix resulting in areas with an undesirable gradation.* And makes a reference to EPC section 460.7.10 "Segregation". The first paragraph of this continues: *Segregation results from the improper handling of the mix at any point during the production, hauling, and paving operations. It can occur as the mix is delivered from the plant to a surge silo, as the mix is discharged into the haul truck from the silo, and as the mix is deposited into the paver hopper by the truck. Some mixes are more prone to segregation than others. Mixes that have a large nominal maximum size aggregate, low binder content, or are gap-graded readily segregate when handled.* The section goes on for another six paragraphs discussing causes and types of segregation, including one paragraph on temperature segregation, and a mention that "Using an MTV that reblends the mix can almost eliminate segregation." The final paragraph links to a reprinted excerpt of an article from the National Asphalt Pavement Association (NAPA) *HMAT* magazine "Superpave – Lessons Learned" by Ron Corun – "Lesson #6 – No Jail Breaks", which further lists causes, cautions, and corrections for segregation in the paving process [Corun, 2003]. So far, this response does not directly give a quantitative definition of segregated pavement, but the response to Question 12 later points to MoDOT Test Method TM-75 "Determining Segregation Using the Nuclear Density Gauge". In this test method, a 50 ft (15 m) profile is established in the segregated area and 11 readings taken every 5 ft (1.5 m) with the gauge at least 1 ft (0.3 m) from the confined and unconfined joints. At each point, collect two one-minute density readings in backscatter mode and average. "If one of the readings varies by more than 1.0 PCF [16 kg/m^3] from the average, take an additional reading. Average the two closest readings and check if they are within 1.0 PCF [16 kg/m^3] and discard the other result." From the 11 readings taken, "determine the highest density reading, the lowest density reading, the average profile density, the drop in density and the maximum density range", where drop in density is the average minus the lowest reading, and maximum range is highest reading minus lowest reading. Criteria are given for "not segregated", (corrective) "action taken", and "remove and replace" following Table 5.

Table 5. Segregation criteria from MoDOT Test Method TM-75. Values are density differences in pcf (1 pcf = 16 kg/m^3)

	Not Segregated	Action Taken	Remove and Replace
Max. Density Range	< 7.0	= or > 7.0 & < 9.0	= or > 9.0
Drop Density	< 3.5	= or > 3.5 & < 4.5	= or > 4.5

Some clarification is given on the "action taken" response: *If a value falls in the "Action Taken" column, then segregation is evident and immediate action shall be taken by the contractor to resolve the issue; however, the severity of the segregation does not warrant removal and replacement. It is not the intent that production will continue day after day when results are in the "Action Taken" range.* A detailed worked out example of measurements and calculations follows.

Washington's response referred to "WSDOT Standard Specification Section 5-04.3(10)B HMA Compaction – Cyclic Density", which defines segregated or low cyclic density areas as *spots or streaks in the pavement that are less than 90 percent of the theoretical maximum density. At the Engineer's discretion, the Engineer may evaluate the HMA pavement for low cyclic density, and when doing so will follow WSDOT SOP 733. A $500 Cyclic Density Price Adjustment will be assessed for any 500-foot [150 m] section with two or more density readings below 90 percent of the theoretical maximum density.* WSDOT SOP 733 is titled "Determination of Pavement Density Differentials Using the Nuclear Density Gauge", but the initial scope reads "Lower pavement density has been related to temperature differentials and areas of "spots, streaks" or visual pavement irregularities. This method uses infrared detection devices and visual inspection to identify areas of potentially low cyclic density." Then a "Temperature Differential Area" in hot mix asphalt (HMA) is defined as "Any area where the temperature of the newly placed HMA pavement is greater than 25° F [14 C°] different than the surrounding area." Aggregate segregation is defined as "'Spots, streaks' or visual pavement irregularities in the newly placed HMA pavement that has a significant difference in texture when compared to the surrounding material." WSDOT SOP 733 goes on to describe how to identify and mark temperature differential areas with an infrared camera or other noncontact device; additionally, areas with "visual pavement irregularities, surface segregation or a significantly different texture" are similarly marked with an added "S" designation. Marked areas are then tested following the "Systematic Density Testing Procedure", which indicates the use of a nuclear density gauge following "WAQTC T 355", a test method which refers to and uses Method B of AASHTO T 355-18. The WAQTC T 355 method describes in detail how to use the density meter and record the results, but does not provide any actual criteria for acceptance. The SOP does specify "If no temperature differentials or streaks greater than 25° F are found or if there are no more than 2 density readings lower than 90 percent found in a 500 ft section, the testing frequency may be reduced. Random checks however, should continue to be made throughout the day and the results recorded." In short, segregated areas are identified either visually or by temperature differentials and checked with a nuclear density gauge following AASHTO T-355-18 Method B to see if they are below 90% of the theoretical maximum density.

The Kansas DOT response to Question 7 was *It is defined by density change along a ~50 ft longitudinal nuclear density profile with readings spaced every 5 feet. The average minus the low reading must be less than or equal to 2.2 lb/cu ft [35 kg/m^3] and the high minus the low reading must be less than or equal to 4.4 lb/cu ft [70 kg/m^3].*

Illinois and Saskatchewan did not provide a quantitative definition, but did provide three-level scales of segregation severity. The lengthy Illinois DOT response begins "Generally, segregation is defined as areas of non-uniform distribution of coarse and fine aggregate particles in the hot-mix asphalt pavement." and breaks down segregation into end-of-load segregation and longitudinal segregation. Then the following is offered: *Segregation can be low, medium, or high severity. Low: A pattern of Segregation where the mastic is in place between the aggregate particles; however, there is slightly more coarse aggregate in comparison with the surrounding acceptable mat. Medium: A pattern of segregation that has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which exhibits some lack of mastic. High: A pattern of segregation what has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which contains little mastic.*

Saskatchewan responded *Segregation is defined within MoH* [Ministry of Highways] *End Product Specification for Asphalt Concrete – 4112: Segregation is defined as an area of the pavement where the texture differs visually from the texture of the surrounding pavement. For the purposes of classifying pavement segregation, only segregated areas greater than 0.1 m^2* [1 ft^2] *and centre-of-paver streaks greater than 1 m in length will be considered. Moderate or severe segregated areas which do not meet these size parameters will be considered Surface Defects.* Then slight, moderate, and severe levels of segregation are defined: *Slight – The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding acceptable mix. Moderate – Significantly more stone than the surrounding mix; moderately segregated areas usually exhibit a lack of surrounding matrix. Severe – Appears as an area of very stony mix, stone against stone, with very little or no matrix. Centre-of-Paver Streak – Appears as a continuous or semi-continuous longitudinal "streak" typically located in the middle of the paver 'mat'.*

Many responding states did not have a definition. For example, the Idaho response was "We do not have a definition. That's a little unnerving." Other states offered something vague, such as Louisiana ("visual inspection; density variations") and Maryland ("separation of coarse aggregate particles"). Utah indicated they had no definition, but the Resident Engineer can reject and that they use smaller aggregate: *We do not have a definition for it as part of a standard acceptance procedure. If it is bad enough that we can see it then the Resident Engineer can reject the material and it is removed and replaced. Asphalt mix segregation has not been a problem with our 1/2 inch* [12 mm] *fine graded materials. We have eliminated 3/4 inch* [19 mm] *and above mixes.*

3.2.2 Who determines if asphalt is segregated

Question 8 asked who has the contractual responsibility to determine if the asphalt is segregated. Results are shown in Figure 6; more than one choice could be selected. The large majority (31, 85.71%) selected DOT inspectors and project personnel as responsible for determining segregation. After that, responsible parties included the paver (15, 42.86%), the prime contractor (13, 37.14%), and third party inspector (11, 31.43%). Only one state (2.86%, ME) chose other, which was identified in the follow-up question response as "DOT construction support from central office".

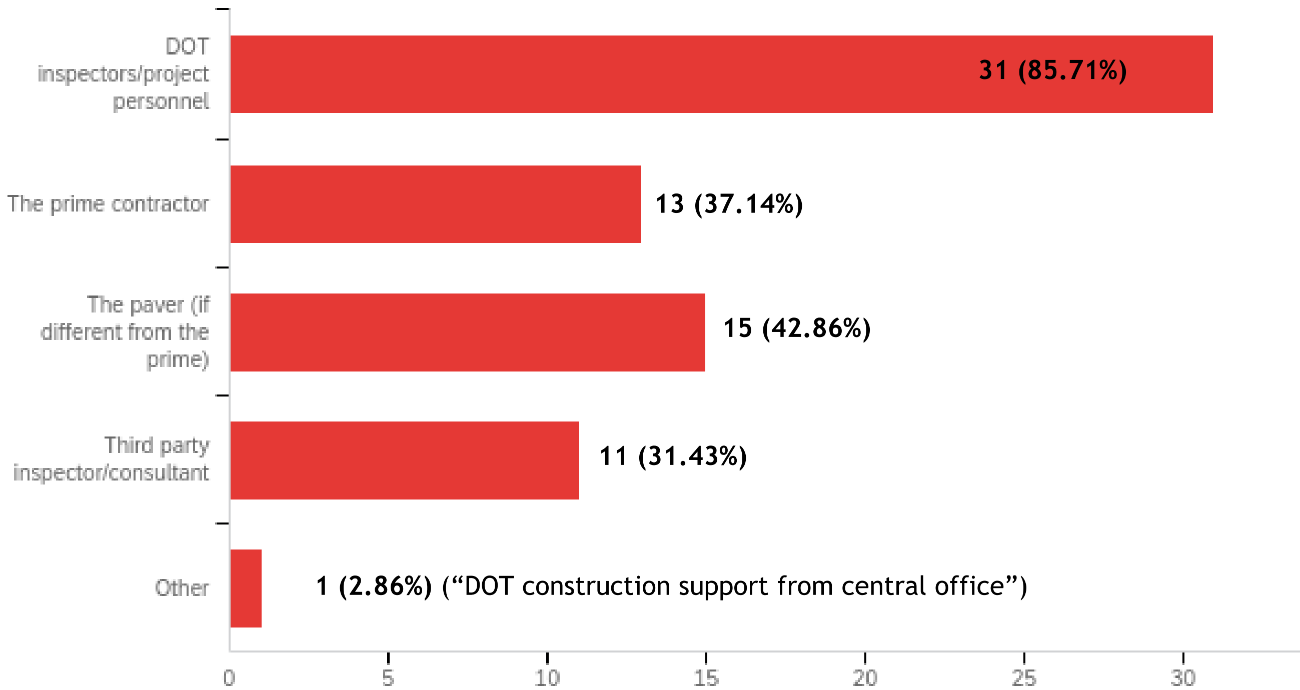


Figure 6. Responses to Survey Question 8: "Who has the contractual responsibility to determine if aggregate is segregated?"

3.2.3 How segregation is determined in the field

Question 10 asked "How does your organization determine segregation in the field at the time of construction? Choose all that apply". "Visual inspection" was an option chosen by all but one state (34, 97.14%); 11 states (28.57%) used field tests, and 9 states (25.71%) used laboratory tests. Nobody selected "other" and only one state (OK) left the question unanswered. The results are summarized in Figure 7.

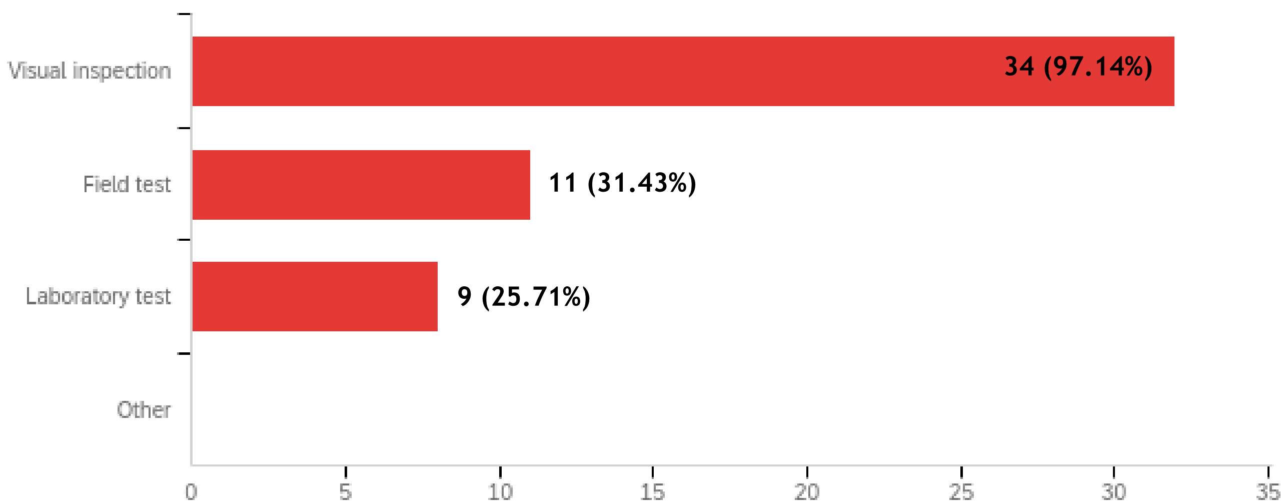


Figure 7. Responses to Survey Question 10: "How does your organization determine segregation in the field at the time of construction?"

The next three questions followed up on the preceding one by asking states to provide details on visual inspection acceptance criteria (Question 11), field tests (Question 12), and laboratory tests (Question 13). Six states (17.14%) did not respond, counting Oklahoma (which did not answer Question 10).

Regarding visual inspection criteria in Question 11, most states (22, 62.86%, ID, LA, TN, MD, VA, MT, AZ, AK, TX, WI, MO, NJ, MN, UT, WA, VT, KS, NV, SC, CA, NY, IN) provided insubstantial responses such as “no visible segregation” (TN), “If it is easily visible, there is an issue” (KS), or “any visibly segregated areas” (TX). Thus, the overwhelmingly common consideration is engineering judgement and experience, but not otherwise specified. Minnesota and Alaska explicitly mentioned “engineer judgement”; Alaska DOT response: “Typically the segregated surface is rougher than the surrounding areas. Training and experience of inspectors are key in detecting segregation.”

That leaves 7 (20.00%, IL, SK, AR, MI, PA*, CO*, FL) substantial responses. Two DOTs (5.71%) provided an ordinal scale; Illinois indicated criteria for Low, Medium, and High severity, while Saskatchewan indicated levels of acceptable (“Slight”), needing repair (“Moderate”), or needing replacement (“Severe”); these scales were discussed under Question 7. Two DOTs (5.71%), Arkansas and Michigan, provided criteria based on the area of segregation. The Arkansas DOT response was *If a pattern of segregation develops, or if segregation occurs over a large area (3 square yards* [3 sq m] *or more), paving shall cease until the problem has been corrected. Visual inspection of the compacted pavement will be made to determine the extent of any segregation.* Michigan DOT said *The visual acceptance criteria for segregation is calculated by summing locations within the length required, which is greater than 215 square feet* [20 m^2] *per 328 feet* [100 m] *of lane length.* This is specified in Michigan DOT Standard Specification for Construction Section 501.03.N.1, Table 501-5, which notes Michigan Test Method. MTM 326 is used to determine segregation.

Table 6. Table 501-5 from the 2012 Michigan DOT Standard Specification for Construction, Section 501.03.N.1.

Table 501-5
HMA Acceptance Factors and Corrective Action

Acceptance Factors (a)	**Length**	**Extent** (b)	**Severity**	**Corrective Action** (c)
Segregation	—	>215 ft^2/ 328 ft LL	Heavy (d)	Replace
Rutting	—	>32 ft	>¼ in average depth over the length of occurrence	Replace
Flushing	—	>108 ft^2/ 328 ft LL	High (e)	Replace
Edge of Paved Shoulder	>33 ft	visible ledges	>3 in	Trim
Crack (g)	any	any	all	Seal (f)

Note: LL = lane length.
a. Acceptance factors apply to all courses except flushing, which applies to the top course only.
b. Extent is calculated by summing locations within the length required.
c. The appropriate corrective action is dependent on the extent and severity of the factor, and on the intended service life of the pavement.
d. Segregation severity will be determinedin accordance with MTM 326. If segregation thresholds are met twice on a paving course, the Contractor may be required to use a Material Transfer Device for the remaining paving for that course at no additional cost to the Department.
e. Flushing must be severe enough to significantly effect surface friction (Friction Number <35).
f. Other corrective action may be required as crack frequency increases.
g. A reflective crack determined, by the Engineer, to be caused by an underlying condition.

Two DOTs (5.71%), Pennsylvania and Colorado, cited specifications. PennDOT repeated the definition of pattern segregation from the Question 7 response and then quoted from Subsection 413.3(h)3a

If the Representative observes pattern segregation that may result in defective pavement, then:

• The Inspector will notify the Contractor of the observed pattern segregation.

• The Contractor may continue to work at their own risk while immediately and continually adjusting the operation to eliminate the pattern segregation from future work

This is more about corrective measures and remediation than about acceptance criteria.

Colorado referred the research team to Section 401.16 of their specifications (“Spreading and Finishing”), which states that if the engineer observes segregation, he or she needs to immediately inform the contractor and mark the suspect areas. Five 10 in (250 mm) cores are collected from the segregated area and another five from nearby non-segregated pavement (within 30 ft (10 m)). The cores are subjected to gradation following CP 46. For the two mix grades X and SX, exceeding the allowable difference of 9% between cores for two key sieves (#8 (2.36 mm) and #4 (4.75 mm)) means the pavement is segregated. Colorado DOT Procedure CP 58 separately covers thermal segregation. Florida responded with a reference to visually selecting areas, from which three cores were collected and sent to the district laboratory for measurement; Louisiana was less specific, simply listing some tests without any further information.

Nine states (25.71%, IL*, PA*, TX*, MO*, MI*, CO*, MN*, WA*, KS*) disclosed field test methods in response to Question 12 and all referred to specifications or provided links. Some used multiple tests, such as Texas (Density profile, nuclear gauge, and non-nuclear gauge) and Colorado (Thermal camera and thermal imaging system in CP 58, mentioned briefly in the preceding paragraph). Five states (14.29%, MO, WA, KS, TX, MI) used nuclear density gauges, and testing for density was thus the most common test cited. Two states (5.71%, PA, MD) mentioned sand patch tests to measure texture; PA has a test method (PTM No. 751), while MD said there was nothing in writing, but that would be their approach. One state (2.86%, IL) mentioned a permeability test. Two states (5.71%, CO and MN) cited thermal equipment.

Missouri DOT said the specification for base layers did not address segregation. This was the only comment specifically on base layers versus surface layers, though Texas DOT explicitly said their method applied to all layers. Texas DOT cited Test Procedure TEX-207-F, Part V, which involves using a nuclear density gauge to take measurements at 5 ft (1.5 m) intervals along a 50 ft (15 m) line offset 2 ft (0.6 m) from either side of a longitudinal streak, a randomly selected region, or a visibly segregated area. A data sheet is provided with the method. Michigan Test Method (MTM) 326 specifies collecting six to fifteen nuclear density gauge measurements inside and near the segregated area. The mean values of the density are compared using the MDOT MBITSEG2 program. Pennsylvania DOT cited a surface macrotexture test per PTM 751 (Discussed under Question 7), which is something like a sand patch test; Maryland's response to Question 11 regarding acceptance criteria was *We do not have one in writing but if we were to do it, we would implement sand test method, which is similar, to find the texture of milling surface*, which is more of a field test than an acceptance criterion. Illinois mentioned a field permeability test: *Although not often used to identify segregation, an after-the-fact investigative field permeability test can help identify difference in compaction levels of adjacent areas of the pavement*. Illinois DOT also provided a link to Appendix B.25, the "Illinois Modified Procedure for Field Permeability Testing of Asphalt Pavements", adapted from an NCAT report [Cooley, 1999], describing a falling head permeability test. Utah mentioned core density and thickness, which sounds more like a lab test than a field test. Utah DOT said they take cores randomly each day and test ten for density and thickness, and at least four for binder content and gradation, though this approach involves laboratory testing. Minnesota cited the PMTP, a type of thermal imaging system ("All layers use PMTP on travelled lanes.").

There were eight responses (22.86%) to Question 13 regarding laboratory tests, of which seven (20.00%, ID, AL*, IL, PA*, CO*, FL*, NV) were substantial; Utah described laboratory tests with cores in Question 12, so those answers are added in here. Seven (20.00%, ID, AL*, IL, PA*, CO*, NV, UT (from an earlier question response)) mentioned aggregate gradation or sieve analysis from cores; four (11.42%, ID, FL*, PA*, UT) mentioned core density; and four (11.42%, ID, AL*, PA*, UT) mentioned binder content.

Alabama DOT stressed testing is in accordance with method ALDOT-389 "Evaluation of Segregated Areas in Hot Mix Asphalt Pavement" on 6 in (150 mm) cores taken at locations selected by the department. The procedure says "The asphalt content and gradation analysis of the core will be used in determining deviations from the Job Mix Formula (JMF) and specification tolerances."; ALDOT-389 is discussed further under Question 7 above. Discussions of tests and criteria used in Pennsylvania and Colorado are also discussed under Question 7. Nevada's terse response was "sieve analysis". Here is Florida DOT's response: *Three 6" [150 mm] diameter cores are obtained in each "segregated" area and the cores are sent to the FDOT District lab for measurement of in-place density. A standard Gmb test is performed. FM 1-T 166 is used and the CoreDry, or equivalent, vacuum drying device is mandatory. The Gmm of the mix as determined for the sublot of material in which the cores came from is used to calculate and average %Gmm of the three cores. The value must be greater than or equal to 89.5%.* This is apparently a reference to Section 330-9.2 of the Florida Standard Specifications for Road and Bridge Construction, which reads: *For areas that the Engineer identifies as being segregated, obtain and submit cores within 30 days of notification. The Engineer will determine the density of each core in accordance with FM 1-T166 and calculate the percent Gmm of the segregated area using the average Gmb of the roadway cores and the QC sublot Gmm for the questionable material. If the average percent Gmm is less than 89.5, address the segregated area in accordance with 330-9.5.* Utah specifically mentioned "We don't have any tests designed just for segregation", though the response to Question 12 indicated cores were collected daily and tested for density, thickness, binder content, and gradation. Illinois DOT also mentioned extraction and gradation analysis as an exceptional procedure: *Although not a typical, standard procedure for Segregation identification and control, an after-the-fact investigative extraction and gradation analysis to compare adjacent pavement areas could be performed to quantify the degree of segregation present.* Idaho responded *Nothing formal. We are trying to monitor relationships between primary (#4 [4.75 mm]) sieve, asphalt binder content, and Gmm by plotting lab values from samples against production quantities.*

There were no responses to Question 14 because nobody chose "other" method in Question 10.

3.2.4 Remedies for segregation

Question 15 asked about what remedies were applied when segregation was encountered. All states except Maine and North Carolina (33, 94.29%) responded, some with more than one remedy. Most agencies (20, 57.14%, OK, LA, PA, MD, MT, AZ, TX, SK, MO, AR*, NJ, CO*, UT, WA, VT, NV, CA, FL, NY, and IN* (mentioned in cited spec)) responded with "remove and replace" or the like. Seven (20.00%, AL*, IL*, PA, TX, MI*, SD, KS) said to suspend work and determine cause. Eight (22.86%, AL*, SK, KS, SC, NY, CA, WI, and MN ("in the past")) included repair; in particular, Saskatchewan mentioned "slurry seal", KS and MN cited chip seal, CA mentioned fog seal, and WI listed microsurfacing. Five (14.29%, ID, AR*, TX, WA, and IN (in cited spec)) mentioned cost deduction or withholding bonus pay. Three (8.57%, MI*, NJ, KY*) mentioned use of materials transfer device (MTD); which New Jersey indicated was required on paving jobs. One state (2.86%) said to certify/inspect equipment (IL*). Indiana* did not cite a specific remedy in their response, but rather said the *Segregated, flushed, or bleeding HMA mixtures will be referred to the Department's Division of Materials and Tests for adjudication as a failed material in accordance with 105.03.* That specification says if the engineer finds the materials not in close conformance with plans, the engineer will determine if the material can be accepted at a modified price, or, *If the Engineer finds the materials or the finished product in which the materials are used or the work performed are not in reasonably close conformance with the plans and specifications and have resulted in an inferior or unsatisfactory product, the work or materials shall be removed and replaced or otherwise corrected with no additional payment.*

Most of these responses are probably not particularly surprising. Saskatchewan did provide some details on what repairs applied: *Potential repairs include: For lower lifts: Slight, Moderate and Centre-of-Paver Streak Segregation on lower lifts will not require repair. Severe Segregation on lower lifts shall require a remove and replace repair unless otherwise approved by the Engineer. For top lift: Slight Segregation on top lift will not require repair. Moderate Segregation on top lift will require a Class II repair (approved slurry seal).* Arkansas mentioned that *Replacement of the material by dumping and spreading by hand or motor grader will be permitted on base and binder courses for areas less than 50 linear feet (15 m) in length.*; otherwise a paver will be required. Illinois DOT listed several potential causes that need to be monitored during the process. In particular, *The Contractor shall submit a written certification that the devices recommended by the paver manufacturer to prevent segregation have been installed and are operational. Prior to paving, the Contractor, in the presence of the Engineer, shall visually inspect paver parts specifically identified by the manufacturer's check list for excessive wear and the need for replacement. The Contractor shall supply the completed check list to the Engineer noting the condition of the parts. Worn parts shall be replaced. The Engineer may require additional inspection prior to placement of the surface course or at other times throughout the work. The Contractor's Annual Quality Control Plan or Addendum shall identify the individual(s) responsible for performing and documenting the daily evaluations. Quality Control Plans and Addendums for subsequent projects shall reflect the corrective actions taken, whether the corrective action was initiated by the Contractor or the Engineer.*

Several states in their responses to Question 15 cited the value of Material Transfer Devices (MTDs) or Vehicles (MTVs). New Jersey noted: *MTV is required on all asphalt projects so we do not see much segregation but if it does occur that area will be milled out and replaced.* The Kentucky Transportation Cabinet concurred: *An MTV is used on larger projects and could be used on others if segregation is an issue.* Michigan indicates *If segregation thresholds are met twice on a paving course, the Contractor may be required to use a Material Transfer Device for the remaining paving for that course at no additional* *cost to the Department*. Wisconsin noted the effect of smaller aggregate: *there are rarely noticeably segregated areas due to the fine graded mixes used.*

Question 16 asked who has the contractual responsibility to determine the applicable remedy for segregation and verify its implementation. Responses are plotted in Figure 8. More than one choice could be selected.

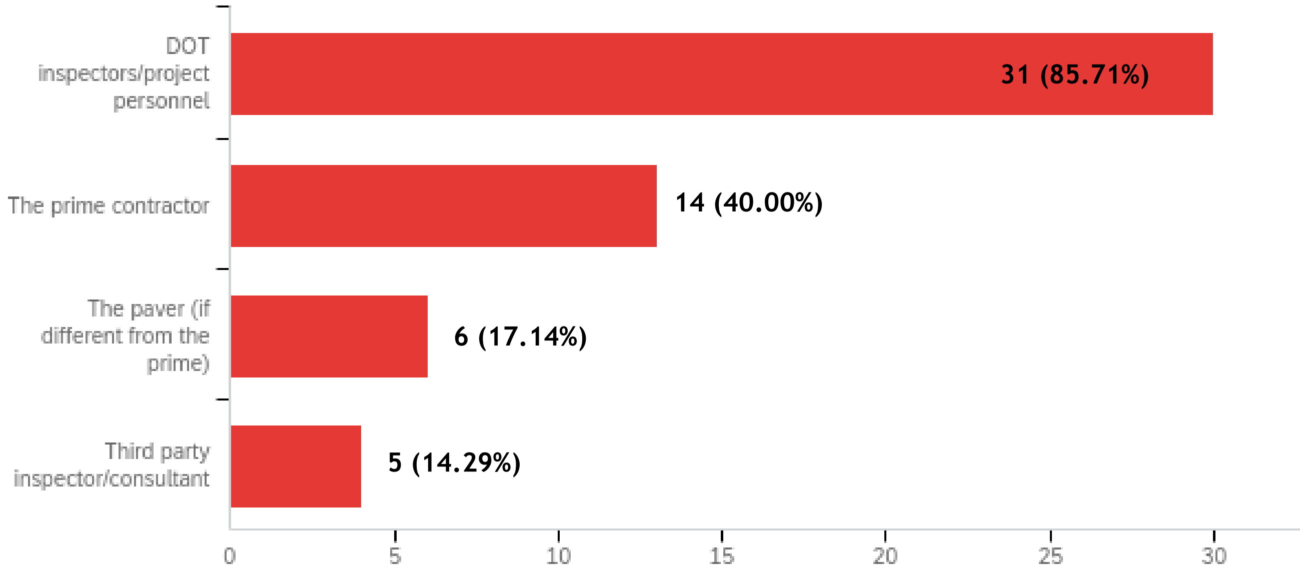


Figure 8. Responses to Question 16 "Who has the contractual responsibility to determine the applicable remedy and determine if it has been implemented?"

Question 17 asked "Is there a process through which the contractor can object to or appeal the Agency-required remedy?" Of the 35 responding DOTs, 21 (60.00%) said "Yes", 12 (34.29%) said "No" and two (5.71%) did not respond. Question 18 asked what the process was for a contractor to appeal an agency-required remedy. The most prevalent answer was to file a claim or follow the claims procedure, chosen by 15 (42.86%, AL, VA, WI, MO, AR, NJ, CO, MN, WA, VT, KS, FL, CA, NY, IN) of respondents. Otherwise, 6 (17.14%, LA, VA, NJ, MI, KS, CA) recommended the contractor work with the engineer; 2 (5.71%, AZ, UT) responded "engineering analysis"; 3 (8.57%, WA, VT, CA) recommended collecting cores; and 2 (5.71%, MO, WA) cited use of the density gauge.

3.2.5 Steps taken to address segregation

Question 19 asked what internal steps had been taken by the DOT to address segregation. Responses are shown in Figure 9. Question 20 followed up with those who responded "other". Responses included mandating use of MTD (TN, NJ), training and certification (ID, SD), prepare a surface inspection guide (SK, literally "The Surface Inspection Guide has not been published yet."), "Communicate problem to subject matter experts in house" (ID), and "We don't have a segregation problem" (VA). Tennessee's answer in full is *We require by spec. the use of MTD (Shuttle buggy) for all asphalt mixes except scratch paving. This seems to have gone a long way into solving the issue. In training we teach to always load trucks from the silo in 3 small dumps.*

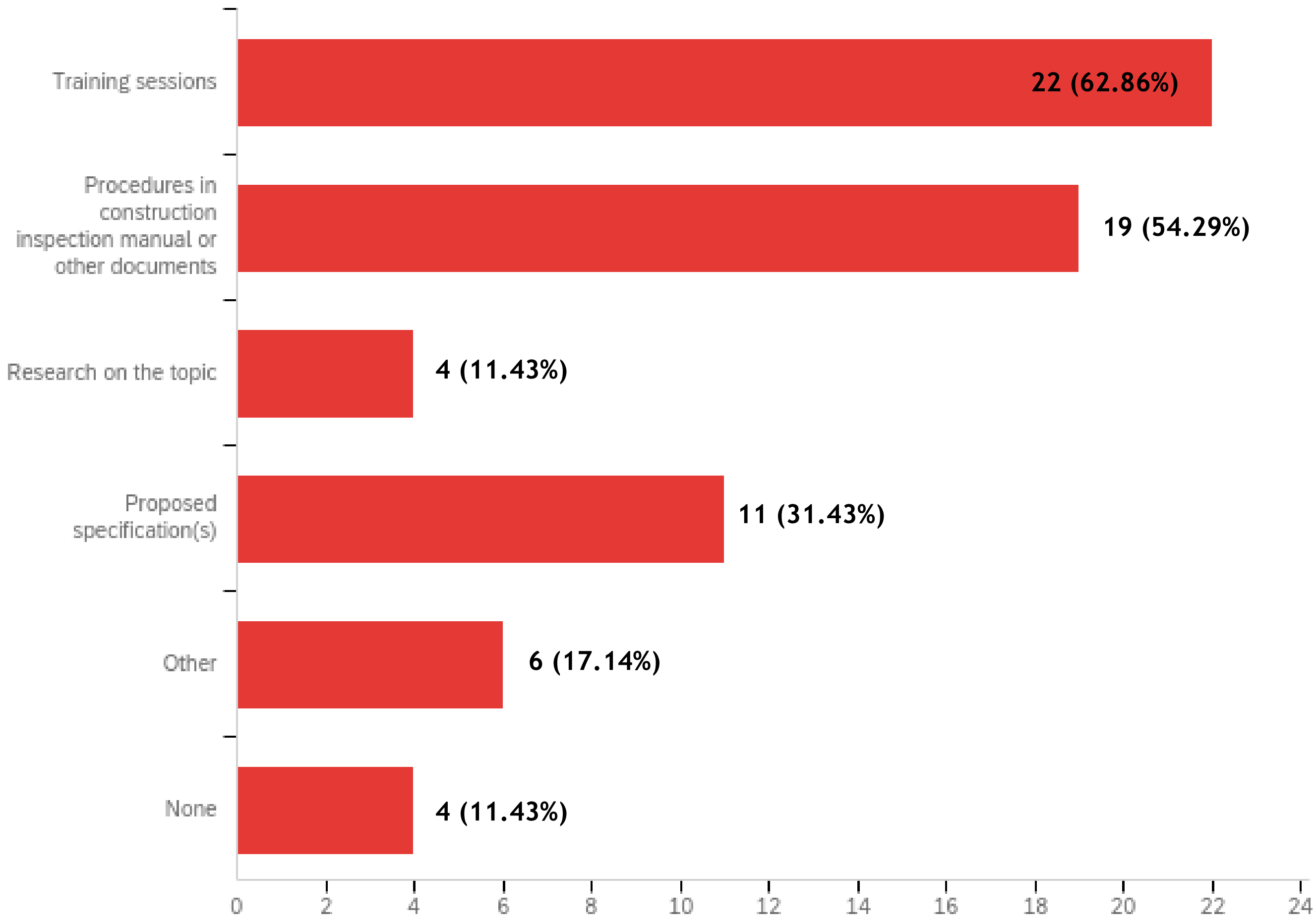


Figure 9. Responses to Question 19, "What internal steps has your organization taken to address segregation?"

In response to Question 21, 18 states (51.43%) provided links to manuals or specifications. When combined with information in other question responses, a total of 24 states (68.57%, AL, IL, PA, MT, AZ, AK, AR, TX, SK, WI, MO, MI, CO, FL, MN, UT, WA, VT, KS, SC, CA, KY, NY, IN) provided a link or specification somewhere in the survey. These links were reviewed and are incorporated above as needed and discussed in the next chapter.

3.3 Review of State DOT Specifications

The construction and materials specifications (C&MS) from the various state DOTs were reviewed for content related to gradation segregation in AC pavement. Locating the specifications for most US states and territories was facilitated by a list maintained on the web by the FHWA at https://highways.dot.gov/federal-lands/specs/state-specifications. It includes the year of most recent publication and the official title. A few jurisdictions were not included in the list (IA, MI, NY, PR, and WI) and in some cases (e.g. HI) the document itself was not searchable. The general approach consisted of searching for "segregat", which would cover "segregation", "segregated", "segregating", and "segregate", then considering only those references pertaining to asphalt concrete pavement; not those referring to Portland cement concrete, aggregate storage, nondiscrimination at rest facilities, separating certain types of charges on invoices, etc. (California in particular used the term in a wide range of contexts). The search expanded to include test methods, supplemental specifications, data collection forms, and other documents where they were referenced or known to exist. This includes all documents referred to in survey answers from the 24 of 35 (68.57%) responding states and provinces, many of which are discussed in the survey chapter above and will generally not be repeated here. The relevant portions of these documents are included in Appendix C, listed in alphabetical order by state name, with territories and Canadian provinces mixed in. Under each state are the C&MS excerpts, followed by the other documents. If a state's C&MS manual did not have specific or novel information on segregation, then no excerpts were included.

This chapter focuses on additional items of interest found beyond what was identified by survey responses. As was the case with the survey responses, most state specifications did not have a clear definition or criteria for segregation, and thus are generally not mentioned here.

The Alberta Ministry of Transportation has published a 16 page *Segregation Rating Manual* [Alberta MOT, 2017]. There is a section on "Classifying segregation severity" which lists three levels of segregation ("Slight", "Moderate", and "Severe") along with "Centre-of-Paver Streak", "Obvious Defect", and "Blemish". The definitions are as follows:

Slight Segregation - The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding acceptable mix.

Moderate Segregation - Significantly more stone than the surrounding mix; moderately segregated areas usually exhibit a lack of surrounding matrix.

Severe Segregation - Appears as an area of very stony mix, stone against stone, with very little or no matrix.

Centre-of-Paver Streak - Appears as a continuous or semi-continuous longitudinal "streak" typically located in the middle of the paver "mat".

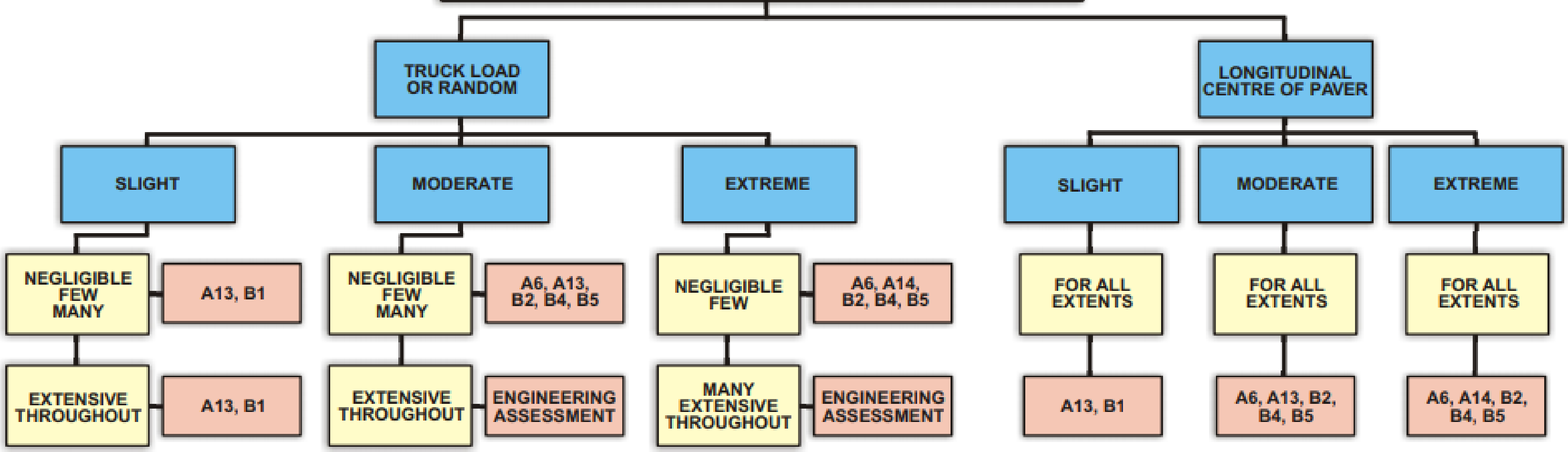
Obvious Defect - Moderate or severely segregated areas which do not meet the size parameters above. Other items that are considered Obvious Defects are areas of excess or insufficient asphalt, improper matching of longitudinal or transverse joints, roller marks, tire marks, cracking or tearing, improperly repaired core holes, etc.

Blemish - A term not defined within the standard specifications but used by some to describe a pavement texture which is not yet considered to be slight segregation (i.e. segregation requirements do not apply).

There is some overlap between the various categories (e.g. between Moderate and Severe segregation). Only segregated areas greater than 0.1 m^2 (0.1 yd^2) or Centre-of-Paver streaks longer than 1 m (1 yd) are to be noted. The manual goes on to summarize the procedures for inspecting and reporting, payment adjustment calculations, conditions when repair is mandated, and appeal procedures. Pre-approved remedies include slurry patch or hot mix path for repair of moderate segregation, while severe segregation requires either an overlay or removal and replacement. The manual then includes 17 photographs in an appendix of various degrees and types of segregation. The neighboring province of Saskatchewan stated in their survey response that a segregation manual is in development; it may well be inspired by the Alberta one. The Alberta manual is also used as a resource by Flexible Pavements of Ohio [Bill Fair, private communication to Shad Sargand, March 5, 2021]. As such it may be useful for training purposes for ODOT.

Alberta's *Guidelines for Assessing Pavement Preservation Treatments and Strategies* [Alberta MOT, 2006] has a series of flow charts for selecting treatments, including one for segregation and another for "longitudinal centre of paver cracks". The flow chart for segregation is reproduced in Figure 10. Portions of the MOT's guidelines for seal coat [Alberta MOT, 2000] as used to repair segregation are given in Appendix C.

FIGURE 8: TREATMENT MATRIX FOR SEGREGATION



SEVERITY DEFINITION
(Reference Spec 3.50.4.7.2)

Slight: The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding area.

Moderate: Significantly more stone than the surrounding mix. Moderately segregated areas usually exhibit a lack of surrounding asphalt and fine aggregate matrix.

Extreme: Appears as an area of very stony asphalt mix, stone against stone with very little or no fine aggregate matrix.

EXTENT DEFINITION

TRUCK LOAD OR RANDOM
(number/lane-km)
(Reference AIT SEAL COAT RATING GUIDELINES)

Negligible - < 5
Few - 5 to 10
Many - 11 to 20
Extensive - 21 to 30
Throughout - > 30

LONGITUDINAL CENTRE OF PAVER
(Percent of Length of Lane Affected)

Few - < 10%
Intermittent - 10 to 20%
Frequent - 20 to 50%
Extensive - 50 to 80%
Throughout - 80 to 100%

Preventative Maintenance Treatments		Surface Treatments		Rehabilitation Treatments	
A1	Crack Fill	B1	Fog Coat	C1	HIR
A2	B&G Crack Fill	B2	Spot Seal Coat	C2	M&I
A3	R&S Crack Seal	B3	Seal Coat	C3	Thin OL
A4	Re-seal R&S	B4	Slurry Seal	C4	Reprofiling and OL
A5	SP (Cracks)	B5	Micro-Surfacing	C5	M&I or HIR and OL
A6	SP (spot)	B6	Reprofiling	C6	Deep M&I
A7	Thermo-Patch			C7	Whitetopping
A8	Micro-Surfacing Patch			C8	Thick OL
A9	Diamond Grind (Cracks)			C9	Structural OL
A10	Shallow Mill and SP (Cracks)				
A11	Shallow M&F (Cracks)				
A12	Deep M&F (Cracks)				
A13	Squeegee Patch				
A14	Mix Patch				
A15	Deep Patch				

INTERPRETIVE NOTES

1) Moderate and extreme severity segregated areas will ravel quickly. Immediate identification and treatment of these areas will reduce the rate of deterioration significantly.

2) Treatment A13 - Squeegee Patch, is generally hand placed using a variety of materials. For slight severity, a application of an emulsified asphalt similar to a fog seal would be appropriate. Moderate and Extreme severity areas could have emulsified asphalt with fine sand mixed in or use of proprietary products for spot patching.

3) Longitudinal Centre of Paver segregation will appear as a straight longitudinal continuous or semi-continuous streak, typically located in the middle of the paved mat.

4) Segregated areas that have experienced ravel should be assessed for treatment using the RAVEL treatment decision tree (Figure 9).

5) When treating Segregated areas, treatments should extend beyond the visible edge of the segregated area.

6) Segregated areas that are left untreated are subject to ravel and premature fatigue cracking.

7) Segregated areas that have been treated as part of the pavement construction process should be monitored for additional treatment on a continuing basis.

8) When an Engineering Assessment is required, the AI & T Guidelines for the Assessment, Rating and Prioritization of Pavements for Seal Coat should be used as the primary procedure.

Segregation

Segregation

Segregation

Figure 10. Alberta MOT treatment matrix for segregation from Guidelines for Assessing Pavement Preservation Treatments and Strategies [Alberta MOT, 2006, p. 38-39].

4 Research Findings and Conclusions

In this chapter, various points from the preceding chapters are consolidated under individual topics to highlight areas of importance and potential findings.

4.1 Definition of segregation

From the survey responses, 13 of 35 respondents (37.14%) said their agency had no definition of segregation; while 16 of 35 (45.71%) provided a definition of some sort or a link. Overall, there was no consistent or standard definition given. The most prevalent definition given, by 9 of the 16 respondents providing a definition or link, said something about separation or non-uniform distribution of aggregate particles, with visual criteria as vague as "bad enough that we can see it" (UT). Two states (5.71%) had three levels of segregation that were defined in qualitative terms (Low, Medium, High (IL) or Slight, Moderate, Severe (SK)). Three states (8.57%) offered a quantified variation in density as measured by nuclear gauge or laboratory analysis. Two states (5.71%) had a criterion based on gradation analysis between cores or differences from the JMF. One state (2.86%) had criterion based on binder content; this was Alabama, who also had criteria based on gradation analysis counted above.

Stroup-Gardner and Brown [2000] defined four levels of segregation (none, low, medium, and high) in their report based on reduced stiffness, increased air voids, and differences in percentage of gradation retained on sieves, noted in Table 7. There is also a table in the report indicating the impact on several mechanical properties with the level of segregation: permeability, resilient modulus, dynamic modulus, dry tensile strength, wet tensile strength, and fatigue life, previously shown as Table 1 on Page 9 above. Elsewhere in the literature there were not enough data on the influence of segregation on these properties.

The criteria for various properties to indicate levels of segregation [Stroup-Gardiner and Brown, 2000, p. 2-3] were then translated to criteria for identification by thermography based on temperature differences between areas or on texture measurements as multiples of the estimated texture depth in example specifications and proposed AASHTO standards, which do not appear to have been since adopted. These criteria appear in the bottom two rows in Table 7, which come from Table 2 and Table 3 on Page 9 above.

Table 7. Definitions of various levels of segregation in NCHRP Report 441, along with corresponding criteria from example specifications. Adapted from Stroup-Gardiner and Brown [2000, p. 2-3, 86, 88].

Segregation level	none	low	medium	high
Increase in air voids	acceptable	0-4%	2-6%	>4%
Stiffness relative to anticipated value	>90%	70-90%	30-70%	<30%
Asphalt content deviation from JMF	<0.3%	0.3-0.75%	0.75-1.3%	>1.3%
Gradation difference	No statistical difference	1 sieve >5% coarser	2 sieves >10% coarser	3 sieves >15% coarser
Thermal spec Temperature difference	≤10C° (18F°)	11C° (20F°) – 16C° (29F°)	17C° (31F°) – 21C° (38F°)	>21C° (38F°)
Texture spec Estimated Texture Depth (ETD)	≤1.15ETD	1.16ETD – 1.56ETD	1.57ETD – 2.09ETD	>2.09ETD

The follow-up NCHRP Synthesis 477 [Stroup-Gardiner, 2015, p. 7], lists four types of segregation: random, longitudinal, thermal, and end of truck load. Standard definitions or descriptions of segregation and a shared understanding of the problem are necessary for the wide variety of agency personnel, contractors, and consultants involved. Stroup-Gardiner also mentions several ways to detect and/or measure segregation: visual observation, surface texture or ride quality, temperature variations (a difference in gradation affects AC composition and thermal properties), and density.

Five states have adopted more specific definitions and criteria for what constitutes segregation. Alabama has comprehensive definitions based on binder content and gradation. They define a segregated area as one where two 6 in (150 mm) core specimens have a liquid binder content more than 0.50% different from the JMF or where the combined gradation analysis differs from the JMF by more than 10% for selected sieves based on maximum aggregate size in Table 4.

Table 4. Sieve sizes used to evaluate segregation for given maximum aggregate size in Alabama (Table I from ALDOT-389-98 [ALDOT, 2009]).

Determination of Sieves Utilized In Segregation Evaluation	
Maximum Size Aggregate	**Sieves Utilized**
1.5 in (37.5 mm)	½ in and No. 4 (12.5 mm and 4.75 mm)
1.0 in (25.0 mm)	3/8 in and No. 4 (9.5 mm and 4.75 mm)
¾ in (19.0 mm)	No. 4 and No. 8 (4.75 mm and 2.36 mm)
½ in (12.5 mm)	No. 8 (2.36 mm)
3/8 in (9.5 mm)	No. 8(2.36 mm)

* with up to 5% retained on the ½" {12.5 mm}

Pennsylvania has two criteria. One is based on the texture depth measured by PTM 751: "The pattern segregation is unacceptable if the difference in average texture depth between non-segregated and segregated areas exceeds 0.024 inch" (0.61 mm). The second is based on gradation of material in core specimens: A pavement is defective if "the summation of absolute deviations from any two sieves is 20% or more from the JMF, the core density is defective, the mixture is defective in asphalt content, or the mixture is defective for percent passing the 75 µm (No. 200) sieve."

Missouri's test method TM-75 is based on collecting 11 cores along a 50 ft (15 m) long profile and determining the maximum density range (maximum - minimum) and the drop density (mean - minimum). The criteria for accepting the pavement, taking action (e.g. repair), and remove and replace are given in Table 5.

Table 5. Segregation criteria from MoDOT Test Method TM-75. Values are density differences in pcf (1 pcf = 16 kg/m^3)

	Not Segregated	Action Taken	Remove and Replace
Max. Density Range	< 7.0	= or > 7.0 & < 9.0	= or > 9.0
Drop Density	< 3.5	= or > 3.5 & < 4.5	= or > 4.5

Kansas uses an approach similar to neighboring state Missouri. The density criteria for acceptable pavement are: "The average minus the low reading must be less than or equal to 2.2 lb/cu ft [35 kg/m^3] and the high minus the low reading must be less than or equal to 4.4 lb/cu ft [70 kg/m^3]."

Washington State DOT defines segregation (aka "low cyclic density") as "spots or streaks in the pavement that are less than 90 percent of the theoretical maximum density". They also define a temperature differential area as "Any area where the temperature of the newly placed HMA pavement is greater than 25° F [14 C°] different than the surrounding area", and these are to be followed up with a density measurement. Temperature behind the paver will identify segregated areas. but not differentiate between gradation and thermal segregation. Determining if the segregation involves gradation issues requires additional examination, and if there is gradation segregation without a difference in temperature, a different means of detection is needed.

4.2 Visual segregation criteria

Nearly all surveyed states (34, 97.14%) identified segregation by visual inspection, but a clear majority (22, 62.86%) did not have any specific criteria, other than it being visible based on engineering judgement. Two states (5.71%) had three-level scales, as noted above. Two states (5.71%) had numerical criteria based on the size of the affected area. In some cases, segregated spots were to be marked for follow-up consisting of coring and laboratory or field tests.

Stroup-Gardiner notes that visual detection is by far the most prevalent, and even declares it the "gold standard" [Stroup-Gardiner, 2015, p. 67]. Stroup-Gardiner also discusses the wide variation in "descriptions of segregation", which is highly problematic when the detection of segregation is so reliant on visual detection methods and engineering judgement [Stroup-Gardiner, 2015, p. 7]. Stroup-Gardiner also discusses the lack of a consistent definition of segregation and the wide variation in "descriptions of segregation", which she notes is highly problematic when the detection of segregation is so reliant on visual detection methods and engineering judgement [Stroup-Gardiner, 2015, p. 7].

Two states have criteria for the amount of segregated area which triggers a stop in paving. For Arkansas, paving is stopped if a segregated area exceeds 3 square yards (3 m^2). In Michigan, the criterion is 215 ft^2 (20 m^2) in a 328 ft (100 m) length of a paved lane of road.

4.3 Field tests for segregation

Nine states (25.71%) responded they had field tests in the survey. Of these, 5 states (14.29% of 35 or 55.56% of the nine states) used nuclear gauge density measurements. One state also mentioned other density measurement methods, including non-nuclear gauge and "density profile". Two states (5.71% of 35 or 22.22% of 9) used thermal equipment as their primary field test. Two other states (5.71% of 35 or 22.22% of 9) cited a sand patch test, one with a written test method and the other without. One state (2.86% of 35 or 11.11% of 9) cited a permeability test.

As noted above, Pennsylvania's surface texture test, PTM 751, indicates segregation if the difference in surface texture depth exceeds 0.024 inch (0.61 mm). Colorado's procedure 58-07 recommends using a temperature gun or IR camera and mark areas with temperature differences of 25F° (14C°) for follow-up density testing to determine segregation, since, as stated before, the thermal method will not identify whether the segregation involves gradation. The states using nuclear gauges or other nondestructive density measurements did not publish specific criteria in their standards, though Michigan Test method (MTM) 326 uses a computer program to determine segregation, which implies there is an algorithm to determine segregation, though those criteria are not published in the specification. Sargand, Kim, and Farrington [2005] found that the PQI Model 300 non-nuclear gauge could accurately measure pavement density, but it is crucial that the gauge is calibrated at the start of each day according to manufacturer's specifications by applying a mix-specific offset. In fact, the calibrated PQI measurements agreed better with the core measurements than did the nuclear gauge.

The sand patch test is a well-recognized standard method (ASTM E 965) for measuring surface texture of AC surfaces, expressed as an estimated texture depth (ETD), used to define various levels of segregation in NCHRP Report 441 [Stroup-Gardiner and Brown, 2000]. ETD can also be measured with high-speed devices, such as ROSAN-V.

McGhee and Flintsch [2003] followed up on NCHRP Report 441 [Stroup-Gardiner and Brown, 2000] by performing a comparison of several pavement texture measurement systems on about a dozen sections of the Virginia Smart Road and at NASA's Wallops airport with different surfaces. The methods tested included the Circular Track (CT) Meter (following ASTM Standard E2157), the sand patch test (following ASTM Standard E965), the International Cybernetics Corporation (ICC) and MGPS high-speed texture measuring systems. The MPGS system represents an evolution of the ROSAN project and presents a mean profile depth (MPD) following ASTM E1845 [McGhee, Flintsch, and Izeppi, 2003, p. 2].

The McGhee and Flintsch [2003] comparison of the CT Meter and the sand patch test found remarkable agreement, stating "For all practical purposes, the output from the two static texture-measuring techniques is equivalent." Hanson and Prowell [2004] obtained similar results in their comparison of the two methods. ORITE's own experiences with the CT Meter and sand patch test on research projects has shown the CT Meter reduces the time needed to take a measurement by a factor of 3, from about 15 minutes down to 5 minutes [Issam Khoury and Joshua Jordan, personal communication, June 23, 2021]. ODOT owns some CT Meters, so this is an approach that can be readily adopted. As a starting point, it may be possible to use the proposed ROSAN-V standard from the Stroup-Gardiner and Brown [2000] NCHRP report with segregation categories similar to Table 3, but with criteria defined in terms of output from the CT Meter and/or sand patch test.

McGhee and Flintsch [2003] further recommend using the CT Meter to collect some "ground truth" measurements for comparison/calibration with other methods. In particular, they noted the "very best agreement was between the MGPS system and the CTM" as both output MPD results, but all comparisons had high correlations. The International Cybernetics Corporation (ICC) system results were typically and consistently about 50% larger than the MGPS MPD values, however the ICC system was still recommended for AC surfaces.

More recent iterations of ROSAN-V and MGPS laser profiling technology include the PathRunner multisubsystem van [Pathway Services, Inc., 2021] and the Automatic Road Analyzer (ARAN) vehicle [Fugro Roadware, 2014], which include multiple laser scan devices to monitor surface texture and rut depth along with asset photographs collected from cameras on all sides, all tied to location data from GPS and DMI. These vehicles are designed primarily to collect inventory and pavement condition data for pavement management systems, rather than directly check particular spots of pavement for segregation, reflecting the change of interest in how the technologies are used.

Meanwhile, the other legacy of ROSAN-V, MGPS, and related technology manifests as a variety of approaches to acquiring and processing image data, which are being considered to in essence quantify the visual inspection and segregation identification process. Baqersad et al [2017, 2018] tried two different statistical approaches to the problem, while Cong et al [2019] took a machine learning approach. Accuracy of these methods ranges from 80% to perhaps 95%. There is no clear consensus or system approaching readiness for widespread field use, though several agencies are investigating.

Stroup-Gardiner and Brown [2000] wrote that IR imaging and ground penetrating radar (GPR) had potential for use in segregation detection. They also established criteria to define the level of segregation, given in the bottom two rows of Table 7 above. Since then, these technologies have evolved, and Landefeld [2014, 2020] makes a case that they are ready for a serious evaluation and possible consideration for adoption. Landefeld [2020] evaluated the rolling density meter (RDM) and the Pave-IR thermal tracker. The RDM provides quick results and covers a much larger portion of the pavement area than coring or nuclear gauges. While the thermal segregation did not always correlate with density measurements, thermal control did help reduce density variations.

Density measurements with a non-nuclear gauge or ground penetrating radar (GPR) are based on the dielectric constant of material. Different devices may give different answers though they operate on the same principle, since the dielectric constant is difficult to measure accurately and is affected by moisture. A slight variation in moisture may lead to an apparent variation in density where there is in fact no segregation.

On the other hand, if stiffness is used to identify segregation, then the challenge is that stiffness, unlike density, depends on temperature. A variation in temperature will lead to differences in stiffness, even if mix is the same and there is no actual segregation.

4.4 Laboratory tests for segregation

Seven states (20%) mentioned laboratory tests, specifically sieve tests to determine gradation from cores. Four states (11.42% of 35 or 57.14% of 7) used density measurements of cores, and four states also used binder content. The density and gradation criteria used to define segregation based on laboratory test results on core specimens are discussed in Section 4.1 above for Alabama, Pennsylvania, Missouri, Kansas, and Washington. In addition, Colorado procedure SP 46 sets the maximum allowable difference in gradation of 9% between cores for two key sieve sizes (#8 (2.36 mm) and #4 (4.75 mm) for both X and SX mixes. Florida DOT uses laboratory tests to determine Gmm of collected cores; percent Gmm < 89.5% indicates segregation.

One major problem with laboratory testing is it introduces a delay between collecting the cores to obtaining results. While an onsite QC laboratory will eliminate the time and risks associated with travel, field measurements are typically faster and can cover a larger portion of the surface area, assuming the equipment is properly calibrated. Speed is important when paving operations are held up to conduct and verify segregation measurements or trace causes of segregation.

4.5 Remedies for segregation

Remedies for segregation, when identified on pavement projects, generally involve either a payment deduction, repair, or removal and replacement, in order of increasing severity. In the survey, 20 (57.14%) of responding agencies cited “remove and replace” as their remedy; seven (20.00%) said to suspend work and identify the cause; eight (22.86%) mentioned some form of repair, five (14.29%) cited cost deduction or withholding bonus pay. In addition, some preventative measures were indicated – three states (8.57%) mentioned the use of MTD, and one (2.86%) emphasized inspection and certification of equipment.

Stroup-Gardiner [2015] lists three remedies (“disincentives”) used for segregation problems. Most common is “remove and replace”. Construction delays caused by additional testing are also noted as a “good disincentive”. However, percent within limits and incremental pay factors were not frequently used.

Tracing causes of segregation is also emphasized through checklists. Four tables in the NCHRP Synthesis [Stroup-Gardiner, 2015, p. 70-73] list many possible causes, and these are echoed in checklists maintained by states, including Kansas (“Segregation Check Points”), Colorado (“Best Practices for Minimizing Segregation” on the reverse of Form 1346 for recording HMA Segregation Data), and Missouri [Corun, 2003].

When using remedies that penalize the paving contractor, it is essential to have a rational and defensible basis for the penalties. It is better to use a proactive approach that prevents segregation in the first place, plus immediate detection and correction of segregation problems. Such an approach will minimize costs and delays. The use of MTDs in conjunction with other paving best practices has reduced instances of segregated pavement.

Larger maximum aggregate size tends to lead to segregation in the asphalt [Stroup-Gardiner, 2015]. Utah has gone as far as to eliminate mixes with aggregate sizes of ¾ in (19 mm) and above. Ohio has asphalt base mixes with maximum aggregate size as large as 1.5 in (38 mm), and these are susceptible to segregation issues when best practices are not adhered to.

4.6 Conclusions

Segregation in asphalt pavement can manifest either as variation in the gradation of the aggregate in the asphalt mix (gradation segregation) or as variation in the temperature (thermal segregation), and both may occur together. Perhaps the primary cause of segregation is improper handling during mixing, transportation, and placement of the asphalt. Segregation is associated with reduced service life and poor pavement performance due to impacts on mechanical properties including resilient modulus, dynamic modulus, tensile strength, and fatigue life [Stroup-Gardiner and Brown, 2000]. Control of segregation is implemented via regular inspections; when segregation is encountered, paving operations may be halted while the cause is determined and fixed or while confirming tests are conducted. This can lead to disputes with contractors over added costs or adjusted payment.

In this project, ODOT is seeking innovative technologies and procedures for monitoring, measuring, and minimizing gradation segregation in AC pavement, thereby obtaining better pavement performance and reducing conflicts with contractors. After conducting a literature review, a survey of state DOTs, and a review of construction specifications, the following can be concluded:

- There is no consistent and clear definition or standard criteria for what constitutes segregation in AC pavement.
- Half a dozen states do have explicit test criteria, which are based on gradation deviations from JMFs, binder content, density variations, surface texture measurements, or temperature differences.
    - Discrepancies from JMF in percentages retained on selected sieves, such as used by Alabama DOT in ALDOT 389-98 [ALDOT, 2009].
    - Pavement macrotexture as measured by PennDOT in PTM 751
    - Density variations such as those used in Missouri (MoDOT Test Method TM-75), Washington (WSDOT SOP 733), or Kansas.
- Another approach to monitoring segregation includes classifying by severity level, as is done in Illinois, Alberta, or Saskatchewan.
- A significant amount of research has been done on different equipment to monitor segregation. The most common parameters measured are temperature, density, texture depth, and stiffness.
- Density can be measured by non-nuclear gauges, ground penetrating radar, or rolling density meter. These devices operate by measuring the dielectric constant. The presence of moisture will affect dielectric properties and thus create inaccurate density measurements.
- Stiffness measurements, such as those made during smart compaction, are affected by temperature.
- Laboratory tests on core specimens will provide a direct measurement of gradation issues, but introduce delays in obtaining results.
- The use of visual inspections is nearly universal in identifying segregation, and most testing mentioned above is conducted on areas identified visually. However, these visual inspections involve engineering judgement and require trained and experienced inspectors.
- The Circular Track (CT) Meter provides results that are equivalent to those from the sand patch test, while being easier and faster to use in the field. ODOT already has CT Meters, so it is worthwhile to verify the accuracy of the results and see if a specification and/or test method can be created.
- The ROSAN-V and successor approaches such as MGPS has been developed into systems such as the Pathrunner Multisubsystem van and Automatic Road Analyzer (ARAN), which are geared towards collecting inventory and pavement management information and not for quickly identifying segregation in the field.

- The other legacy of ROSAN-V is the ongoing exploration of imaging technologies and algorithms to identify segregated pavement. A handful of states are researching this approach, but so far none of them are being implemented.
- Segregation is more prevalent in mixes with larger maximum aggregate size, which are used predominantly in base layers. AC base layers in Ohio often use aggregate as large as 1.5 in (38 mm), which has a higher potential for segregation.
- Large aggregate and binder content deviation from JMF are two factors which increase the potential for segregation.
- More specific information on how the level of segregation affects pavement performance than currently provided in the literature will help improve remedies.
- The damaging impacts of segregation on pavement performance may depend on which layer has the segregation.
- In their investigation of asphalt base course projects in Ohio, Green et al. [2018] found three of seven sections with segregation had high Cantabro mass loss (> 30%), low TSR (0.51 or less), and high average in-place air content (> 7%). Further research is needed to determine the extent to which the relationship holds and to determine if Cantabro mass loss testing is a viable tool for verifying segregation in AC pavements. In particular, a threshold mass loss value indicating segregation would make such a test very useful.

5 Recommendations for Implementation

The research findings and conclusions drawn above point to several recommendations for implementation:

- Currently ODOT and Flexible Pavements of Ohio (FPO) conduct courses for Mix Design Level II and III. Information on segregation can be added to this curriculum, either by incorporating the material to the existing courses or by creating a new course devoted to segregation. Either way, this material should also be available to ODOT employees and people from private sector through the training program. However, since these courses are aimed at laboratory personnel, a new training program or course could be added for field inspectors with a focus on inspecting pavement and detecting segregation and offered in a similar manner. The ODOT Construction Manual of Procedures can be updated to reflect best practices for detecting segregation and assessing severity.
- Because the potential for segregation increases with larger aggregate or reduced binder content, ODOT can review specifications for HMA mix designs to identify possible opportunities to mitigate segregation. ODOT can also consider a testing approach similar to Alabama DOT Method with criteria based on binder content and gradation.
- Proactively monitor temperature and/or density at the paver to identify segregation during construction. ODOT's Pavement Office [Landefeld, 2014, 2020] has made some significant progress in this area regarding PMTP and RMD, which can serve as a basis for follow up work.
- The proactive approach to controlling segregation can use real-time monitoring of temperature or density to trigger an alarm to pause paving operations so that the cause of potential segregation can be located and immediately addressed to minimize the disruption and delay of paving progress. The alarm criteria will need to be determined and evaluated.
- The use of density measurements in the field with a nuclear density gauge, as is done in Washington, Missouri, and Kansas, can also be evaluated for use in Ohio.
- Texture measurements or international roughness index (IRI) are more useful for determining penalties after the fact rather than for corrective action during paving. Also, this approach only measures problems with the surface course; segregation in intermediate and/or base layers requires making measurements before the next layer is applied, which may not be a realistic option.
- Gather more performance-based data to document the relationship between performance and segregation, including each layer of Ohio mix designs.
- A laboratory study of segregation could be conducted to better understand mechanisms and effects of segregation. One can start with specimens created with an ideal mix, then vary parameters to add some segregation effect in subsequent specimens, then compare the performance of the cores to measure the effect of the variation in parameter. Promising and significant results could then be validated in the field.
- The asphalt base evaluation project report [Green et al, 2018] found a relationship between high Cantabro mass loss and segregation in asphalt base cores. Further studies can deepen understanding of this relationship and identify a threshold value for Cantabro mass loss.

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Appendix A: Example Specification and Proposed Drafted AASHTO Provisional Standard for using ROSAN-V Surface Texture Measurements to Detect Segregation, Appendix J (p. 87-89) and Appendix L (p. 93-95) from Stroup-Garner and Brown [2000].

APPENDIX J

EXAMPLE SPECIFICATION FOR USING ROSAN$_v$ SURFACE TEXTURE MEASUREMENTS TO DETECT AND MEASURE SEGREGATION

Section 1. Definitions.

Segregation: is the lack of homogeneity in the hot-mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es).

Constituents: include asphalt, aggregate, and air voids.

Temperature segregation: refers to portions of the mix with significantly different temperatures. This type of segregation can occur as the result of the surface of the mix cooling in the haul truck, cold mix in the paver wings getting raised immediately prior to the addition of fresh hot mix, and any anomalies in the paving operations that result in areas with significantly different temperatures.

Gradation segregation: is the separation of the coarse and fine aggregate fractions.

Sieves: Gradation results are based on using the following sieves in the analysis: 37.5, 25, 19, 12.5, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.072 mm.

Low-level segregation: will have mix stiffness (resilient modulus) of between 70 and 90 percent of the mix in the nonsegregated areas; air voids will be up to 4 percent higher. When gradation segregation is present, there will be one or more sieves that are at least 5 percent coarser than the nonsegregated area with a corresponding decrease in asphalt content of between 0.3 and 0.75 percent.

Medium-level segregation: will have mix stiffness (resilient modulus) of between 30 and 70 percent of the mix in the nonsegregated areas; air voids will be between 2 and 6 percent higher. When gradation segregation is present, there will be two or more sieves that are at least 10 percent coarser than the nonsegregated areas with a corresponding decrease in the asphalt content of between 0.75 and 1.3 percent.

High-level segregation: will have mix stiffness (resilient modulus) of less than 30 percent of the mix in the nonsegregated areas; air voids will be more than 5 percent higher. When gradation segregation is present, there will be three or more sieves that are at least 15 percent coarser than the nonsegregated areas with a corresponding decrease in the asphalt content of more than 1.2 percent.

Section 2. Identification of Segregated Areas.

Segregated areas will have textures either statistically coarser or finer than the texture in a nonsegregated area. The units for texture measurements shall be the estimated texture depth (ETD) as defined in ASTM E1845. This value uses the ROSAN$_v$ mean profile depth (MPD) to estimate the texture depth (i.e., ETD) obtained with the sand patch test (ASTM E965).

Section 2.1. Setting Limits for No, Low, Medium, and High Levels of Segregation.

Visually identify and mark an area of the mat with acceptable textures. Use the ROSAN$_v$ equipment to determine the average texture depth in this area. This value can be used to compute the texture ratios in the test sections. Alternatively the anticipated texture in a nonsegregated area can be estimated using information on the maximum aggregate size, percent passing the 4.75 mm sieve, and the coefficients of curvature and uniformity:

$$\text{Predicted ETD} = 0.01980\ (\text{max. agg. size}) - 0.004984\ (\%\ \text{pass. } 4.75\ \text{mm}) + 0.1038\ (C_c) - 0.004861\ (C_u)$$

Where:

Predicted ETD = estimated texture depth from sand patch test in mm
Max. Agg. Size = smallest sieve size with 100 percent passing.
% pass. 4.75 mm = the percent passing the 4.75 mm sieve
C_c = coefficient of curvature = $(D_{30})^2/(D_{10}\,D_{60})$
C_u = coefficient of uniformity = D_{60} / D_{10}
D_{10} = the sieve size, in mm, associated with 10 percent passing
D_{30} = the sieve size, in mm, associated with 30 percent passing
D_{60} = the sieve size, in mm, associated with 60 percent passing

Upper and lower texture limits used to detect and measure low, medium, and high levels of segregation are obtained by multiplying either the measured nonsegregated area texture or the predicted ETD by the appropriate factor from Table J-1. For example, a pavement surface will be considered to have

TABLE J-1 Factors for the predicted ETD for detecting and measuring various levels of segregation

Limit	Fine Level Segregation	No Segregation	Low Level Segregation	Medium Level Segregation	High Level Segregation
Lower	< 0.75	0.75	1.16	1.57	> 2.09
Upper	None	1.15	1.56	2.09	None

no segregation if all texture measurements are between 0.75 and 1.15 times the predicted texture.

Section 3. Extent of Each Level of Segregation.

One lot shall be 5,000 feet of one lane width. Each lot shall be subdivided into ten 500 foot sublots. Three sublots shall be randomly selected for testing. The MPD will be measured longitudinally at quarter points for lanes 12 feet and wider for each sublot tested (Figure J-1). The MPD will be measured longitudinally at third points for lanes less than 12 feet wide for each sublot tested. The modified ROSAN$_V$ software will determine the number of MPD measurements that fall within the limits for each level of segregation. The percent of each level of segregation in each sublot will be

$$\% \text{ Segregation} = \frac{\text{Number of data points within segregation limits}}{\text{Total number of data points}} \times 100$$

The number of data points at any given level of segregation will be the sum of the data points collected for all longitudinal passes conducted for each sublot. The percent of each level of segregation for the lot will be the average of sublot percentages for each level of segregation.

Section 4. Pay Factors and/or Correction of Segregation.

Areas with a low level of segregation or higher will be assessed a pay adjustment factor at the discretion of the agency.

Areas with a medium level either will have a pay adjustment factor assessed, or the contractor will be required either to repair or to remove and replace the area. The choice of remedial action will be at the agency's discretion. When the choice is to remove the segregated area(s), the segregated areas(s), as well as 50 feet on either side of these areas, will be removed and replaced.

Any areas with a high level of segregation will be removed and replaced. The areas to be removed and replaced will be the segregated areas and a minimum of 50 feet on either side of each area.

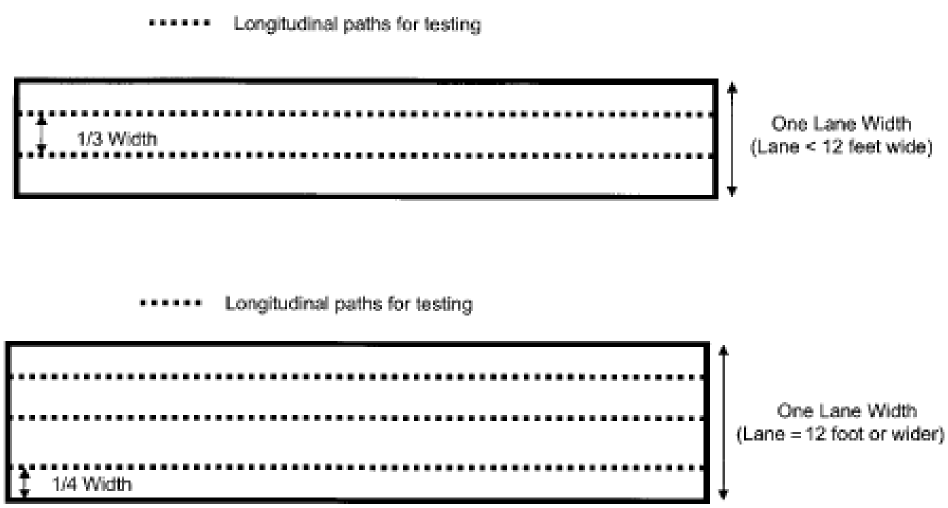


Figure J-1. Longitudinal paths for measurement for each sublot.

Section 5. Disputes.

All areas suspected of having a level of segregation other than "no segregation" shall be marked for additional testing. Each area marked shall be identified with the suspected level of segregation. Marked areas shall be grouped by the anticipated level of segregation for further testing. The inspector shall determine the number of cores to be taken from each group. Standard testing to determine density, air voids, asphalt content, and gradation shall be used to confirm the level and extent of segregation.

If the level of segregation indicated by the texture measurements is confirmed by the laboratory testing of the cores, the cost of the coring and testing shall be paid by the contractor.

APPENDIX L

PROPOSED DRAFT AASHTO PROVISIONAL STANDARD

STANDARD TEST METHOD FOR USING ROSAN$_v$ LASER SURFACE TEXTURE MEASUREMENTS TO IDENTIFY SEGREGATION IN HOT-MIX ASPHALT PAVEMENTS

MAY 1999

1. SCOPE

1.1 This test method covers the identification of areas of segregated hot-mix asphalt in a finished pavement mat.

1.2 This test method uses the ROSAN$_v$ high-frequency laser sensor system to measure the texture depth of a longitudinal profile of a pavement section.

1.3 Statistically based limits can be used to determine the percent of the profile with none, low, medium, and high levels of gradation segregation.

1.4 The values stated in millimeters are to be regarded as the standard.

1.5 *This standard may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety problems associated with its use. It is the responsibility of anyone using this practice to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards

- T166 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
- T168 Sampling Bituminous Paving Mixtures
- T209 Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- T269 Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures

2.2 ASTM

- ASTM PS 90 Asphalt Content of Hot Mix Asphalt by the Ignition Oven Method
- ASTM D4123 Indirect Tension Test for Resilient Modulus of Bituminous Mixtures

3. SIGNIFICANCE AND USE

3.1 The estimated texture depth (ETD) is determined for a baseline of 500 mm using the ROSAN$_v$ laser surface texture measurement system. The distance measurements corresponding with the measurements can be obtained either from a digital distance encoder or by using the optical trigger option.

3.2 Either an average texture in a non-segregated area or mix design information is used to determine an anticipated texture depth in the non-segregated areas. Mix information used includes the maximum size of aggregate, the percent passing the 4.75 mm sieve, and the coefficients of curvature and uniformity.

3.3 This estimated non-segregated area texture and texture ratios that define the limits between none, low, medium, and high segregation can then be used to sort the raw ROSAN$_v$ data. The number of data points in each segregation level divided by the total number of data points provides an estimate of the percent of each level of segregation present.

4. DEFINITIONS

4.1 *Segregation*: is the lack of homogeneity in the hot-mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es).

4.2 *Constituents*: include asphalt, aggregates, and air voids.

4.3 *Gradation segregation:* is the separation of the coarse and fine aggregate fractions.

4.4 *Temperature segregation:* refers to portions of the mix with significantly different temperatures. This type of segregation can occur as the result of the surface of the mix cooling in the haul truck, cold mix in the paver wings being flipped into the hopper immediately prior to the addition of fresh hot mix, and any anomalies in the paving operations that result in areas with significantly different temperatures.

4.5 *Texture ratios:* are the ratios of textures in segregated areas to those in non-segregated areas.

4.6 *Low-level segregation*: will have texture ratios between 1.16 and 1.56. It is anticipated that these areas will have mix stiffness (resilient modulus) of between 70 and 90 percent of the mix in the non-segregated areas; air voids will be up to 2 percent higher. There will also be a decrease in the asphalt content of between 0.3 and 0.75 percent and a statistically measurable decrease in the percent passing at least one coarse sieve.

4.7 *Medium-level segregation:* will have texture ratios of between 1.57 and 2.09. It is anticipated that these areas will have mix stiffness (resilient modulus) of between 50 and 70 percent of the mix in the non-segregated areas; air voids will be between 2 and 6 percent higher. When gradation segregation is present, there will also be a decrease in the asphalt content of between 0.75 and 1.3 percent and a statistically measurable decrease in the percent passing at least one coarse sieve.

4.8 *High-level segregation:* will have texture ratios greater than 2.09. It is anticipated that these areas will have mix stiffness (resilient modulus) of less than 50 percent of the mix in the non-segregated areas; air voids will be more than 5 percent higher. When gradation segregation is present, there will also be a decrease in the asphalt content of greater than 1.3 percent and a statistically measurable decrease in the percent passing at least one coarse sieve.

5. APPARATUS

5.1 *ROSAN$_v$ hardware* which consists of:

5.1.1 Selcom laser sensor head optocator model number 2008.

5.1.2 Selcom probe processing unit (PPU).

5.1.3 Selcom OIM-II signal conditioner and box.

5.1.4 Carrying case for sensor and equipment.

5.1.5 National Instruments DAQCard-AI-16E-4.

5.1.6 National Instruments PCMCIA adapter 183569A-01.

5.1.7 National Instruments 2M Calbe 182419B-02.

5.1.8 National Instruments Terminal Block CB68LP.

5.1.9 Notebook computer.

5.2 Software.

5.2.1 *ROSAN$_v$-TMR software* for collecting, storing, and processing laser data.

5.3 *Digital distance encoder*-which works off of the vehicle speedometer and can be wired into the ROSAN$_v$ data collection system.

5.4 *Optical triggers*-3-meter lengths of rubber hose with a diameter of about 25 mm (1 inch) can be used for optical triggers in place of the digital distance encoder or speed option in the software. A minimum of one hose is needed at beginning and end of the test section.

5.5 *Miscellaneous*-include such items as duct tape for securing the hose to the pavement, paint, and markers.

5.6 *Bumper Bracket*-for mounting the laser sensor to the vehicle.

6. PROCEDURES

6.1 Mount the bumper bracket on the vehicle bumper so that the desired transverse path can be evaluated.

6.2 Attach the laser sensor so that the sensor lens is 15.3 inches above the surface of the pavement. Remove the sensor lens cover.

6.3 Attach the cabling that connects the sensor to the data collection system inside the vehicle.

6.4 Attach the cable from the $ROSAN_v$ system to the computer.

6.5 Provide 12-volt power from the vehicle to the $ROSAN_v$ system.

6.6 Turn on the $ROSAN_v$ system and check to see that the green lights are lit in about the middle of the light display. This provides a check that the sensor is mounted at the correct height. If the lights show yellow, adjust the sensor height.

6.7 Boot the computer and start the $ROSAN_v$ software.

6.8 Enter data as requested on software window.

6.9 Once the software is ready for data collection, position the vehicle in the lane to be tested and operate it at the speed entered into the software. Start the data collection when the vehicle is both in position and at the appropriate speed.

6.10 Stop the data collection after the desired length of section has been tested by clicking on the left-mouse button. Data should not be collected for more than 15 seconds at a time. This will ensure that the data files are of a manageable size for storing and data analysis.

6.11 Check to see that data was actually collected by reviewing data per software supplier instructions.

7. CALCULATIONS

7.1 Develop the texture limits for each level of segregation for a given project.

7.1.1 If the non-segregated area texture is to be estimated

7.1.1.1 Estimated texture depth, ETD, in the non-segregated areas using the maximum size of aggregate, the percent passing the 4.75 mm sieve and the coefficients of curvature and uniformity:

$$ETD = 0.01980\,(\text{max. agg. size}) - 0.004984\,(\%\ \text{pass. } 4.75\text{ mm}) + 0.1038(C_c) - 0.004861(C_u)$$

Where:

ETD = estimated texture depth in mm
Max. Agg. Size = smallest sieve size with 100 percent passing
% pass. 4.75 mm = the percent passing the 4.75 mm sieve
C_c = coefficient of curvature = $(D_{30})^2 / (D_{10}\, D_{60})$
C_u = coefficient of uniformity = D_{60} / D_{10}
D_{10} = the sieve size, in mm, associated with 10 percent passing
D_{30} = the sieve size, in mm, associated with 30 percent passing
D_{60} = the sieve size, in mm, associated with 60 percent passing

7.1.2 Calculate the limits for none, low, medium, and high levels of segregation:

7.1.2.1 No segregation limits, in mm:

$$\text{Upper ETD Limit}_{no} = \text{Non-segregated area ETD} * 1.15$$

$$\text{Lower ETD Limit}_{no} = \text{Non-segregated area ETD} * 0.7$$

Note 1: Although a lower limit on texture is set, this limit has not been verified with laboratory testing

7.1.2.2 Upper low segregation limit, in mm:

$$\text{Upper ETD Limit}_{low} = \text{ETD} * 1.56$$

7.1.2.3 Upper medium segregation limit, in mm:

$$\text{Upper ETD Limit}_{medium} = \text{ETD} * 2.02$$

7.1.3 Import the $ROSAN_v$ data file into any spreadsheet program.

7.1.3.1 Divide each data point by the ETD for the non-segregated area.

7.1.3.2 Sort the data so that the number of data points can be counted with textures between the:
Lower and upper ETD_{no} limits (no segregation),
Upper ETD_{no} and upper ETD_{low} limits (low segregation),
Upper ETD_{low} and upper ETD_{medium} limits (medium segregation), and
Greater than upper ETD_{medium} limit (high segregation).

7.1.3.3 The estimated percent of the longitudinal path tested with a given level of segregation can be obtained dividing the number of data points in each level of segregation by the total number of data points.

8. REPORT

8.1 The report shall include the following information:

8.1.1 How the distance was measured.

8.1.2 Whether the non-segregated area ETD was measured and averaged or estimated from mix properties.

8.1.3 The starting point of the measurements.

8.1.4 The lane designation, the transverse position in the lane, and the reference point (e.g., centerline) from which the transverse location was measured.

8.1.5 The predicted ETD, the upper and lower limits for ETD_{no}, and the upper limits for ETD_{low} and ETD_{medium}.

8.1.6 The percent of the data within each level of segregation.

8.1.7 The corresponding locations of each data point in the medium and high levels of segregation.

9. PRECISION AND BIAS

9.1 The nature of this test method does not allow for a round-robin testing program. Consequently, the precision and bias of this test method are unknown at this time.

Appendix B: Survey results.

Some comments on the Qualtrics report from March 29, 2021, 9:30 MDT:

- Q1 was the initial block where we described the survey, so there are no responses
- Q2-Q6 was where we collected contact information. This is summarized on one page.
- Q4 is the agencies which responded; These are listed in order people completed the survey, with the most recent first and earliest last

Questions fall into two different types – multiple choice or written answer.

For the multiple-choice questions, responses are summarized in bar charts (Q8, Q10, Q16, **Q17**, Q19, **Q22**). More than one response could be selected for most of these questions (Q8, Q10, Q16, Q19). Q17 and Q22 were Yes/No. For each of these, Qualtrics provided a graph and the first table, with percentages based on the total number of responses, which excluded blanks and counted a state choosing more than one option as more than one response. These percentages add to 1000%. A second table has been added with percentages of the total number of responding agencies (35) and counting the blank responses ignored by Qualtrics. The Qualtrics default report format has generally been retained (headers, etc.).

For the written answer questions, these fall into three types in terms of the responses:

1. Everyone or nearly everyone responded. (Q7, Q11, Q12, Q15, Q21) For these there is a table listing every state, and for those that did not respond to the question there is "(no response)". States that were not asked a question because it was a conditional question are crossed out.
2. Some or a few states responded. (Q13, Q18). For these there is a complete table also, with states not asked the question crossed out. Six states responded to Q20, so the non-responses from states not asked the question have been removed.
3. None or one agency responded. (Q9, Q14) In these cases the option was in case "other" was chosen for a previous question, either nobody selected "other" (Q14) and this follow-up didn't appear in their survey, or there was one response which was incorporated into the graph and chart (Q9).

Qualtrics provided the responses as a single column table – a column on the left was added to indicate which states provided which responses. Responses are listed in order with the most recent first.

Responses:

32 states responded completely: ID, AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, WI, MO, AR, MI, NJ, CO, MN, UT, WA, SD, VT, KS, NV, SC, FL, CA, KY, NY, IN. The last recorded responses were March 24.

One Canadian province responded: SK (Saskatchewan), on February 10.

There were two incomplete responses (both 45% complete): NC, on February 15, and ME on March 10. These states answered or viewed questions 1-10, and stopped at Q11.

Other incomplete responses were deleted, as these were from people who did not enter a name or affiliation. Some of these appeared to be people skimming through the survey to review the questions before formulating answers or to determine if they wanted to respond. Others were test runs by the TAC or research team. None of these had written responses.

Some comments on responses to specific questions:

- Q7: Only KY had no response regarding definition of AC Segregation; NV and OK responded "NA". Some others indicated segregation wasn't formally defined.
- Q9: There was one response; only one respondent selected "other" for Q8.
- Q11: ME, AL, OK, NC, SD, and KY did not provide visual inspection criteria. Some others entered NA or N/A, though everyone except OK selected the "visual inspection" option for Q10.
- Q12: Non-respondents were ME, ID, AL, OK, NC, LA, TN, MD, VA, MT, AZ, AK, SK, WI, AR, WA, SD, VT, NV, SC, FL, CA, KY, NY, IN. These are states who mostly did not select the "field test" option for Q10
- Q13: Only 8 states have lab tests: ID, AL, IL, PA, CO, UT, NV, FL
- Q14: no respondents; nobody selected "other" for Q10
- Q18: 22 states responded.
- Q20: 6 states/provinces responded, those who selected "other" for Q19: ID, TN, VA, SK, NJ, SD
- Q21: States not supplying additional links/information: ME, ID, AL, OK, NC, LA, PA, TN, VA, AR, MI, NJ, SD, NV, FL
- Note some states provided spec numbers or links in earlier question responses (e.g. AL)
- Q22: Only NV and VA said they did not want to be contacted for follow-up, and ME, WA, and NC had no response.

Where appropriate, more summary details are provided immediately after each question below.

Contact information summary

State	Q2 Name:	Q3 Position or title:	Q4 Agency:	Q5 Telephone	Q6 Email Address:	Q22 Followup OK?
ME	Richard Bradbury	Director of Materials Testing	Maine DOT			
ID	John Arambarri	State Pavements Engineer	Idaho Trans, Dept.			Yes
AL	Scott George	State Materials and Tests Engineer	ALDOT			Yes
IL	Tom Zehr	HMA Implementation Engineer	Illinois DOT			Yes
OK	Kevin Suitor	Bituminous Branch Manager	OK DOT			Yes
NC	Jerry Simmons	Acting Pavement Specialist	NCDOT M&T Field Section			
LA	Samuel Cooper III	Materials Research Administrator	LADOTD			Yes
PA	Timothy L. Ramirez	Engineer of Tests	Pennsylvania DOT			Yes
TN	Matthew Chandler	State Bituminous Engineer	Tennessee DOT			Yes
MD	Chandra Akisetty	Chief of Asphalt Division	MDOT			Yes
VA	Sungho Kim	Statewide Asphalt Program Manager	Virginia DOT			No
MT	Oak Metcalfe	Materials Engineer	Montana DOT			Yes
AZ	JesÃºs Sandoval-Gil	State Materials Engineer	Arizona DOT			Yes
AK	Steve Saboundjian	State Pavement Engineer	Alaska DOT&PF			Yes
TX	Travis Patton	Bituminous Branch Manager	TxDOT			Yes
SK	Daniel Gorin	Senior Surfacing Engineer	Saskatchewan MOH			Yes
WI	Steve Hefel	HMA Supervisor	WisDOT			Yes
MO	Willie Johnson	Field Materials Engineer	Missouri DOT	Contact information redacted		Yes
AR	Colton Cowles	Staff Construction Engineer	Arkansas DOT			Yes
MI	John Barak	HMA Engineer	Michigan DOT			Yes
NJ	Stevenson Ganthier	Principal Engineer	New Jersey DOT			Yes
CO	Craig Wieden	State Materials Engineer	Colorado DOT			Yes
MN	Curt Turgeon	State Pavement Engineer	Minnesota DOT			Yes
UT	Howard Anderson	UDOT State Asphalt Engineer	Utah DOT			Yes
WA	Kurt R Williams	State Materials Engineer	Washington State DOT			
SD	Rick Rowen	Bituminous Engineer	South Dakota DOT			Yes
VT	Ryan Darling	Construction Paving Engineer	VTrans			Yes
KS	Blair Heptig	Field Materials Engineer	Kansas DOT			Yes
NV	CHARLIE PAN	Engineer	NDOT			No
SC	Cliff Selkinghaus	Asphalt Materials Manager	SCDOT			Yes
FL	Greg Sholar	Bituminous Engineer	FDOT			Yes
CA	Kee Foo	Sr. Transportation Engineer	California DOT			Yes
KY	Jarrod Stanley	Research Coordinator	Kentucky Trans. Cabinet			Yes
NY	Zoeb Zavery	PE 1	New York State DOT			Yes
IN	Nathan awwad	Asphalt Engineer	Indiana DOT			Yes

Default Report

Survey of State DOTs on segregation in asphalt concrete
March 29th 2021, 9:30 am MDT

Q7 - How does your organization define segregation in AC pavement in its construction and materials specifications?

- Total responses (excludes blanks) (34): ME, ID, AL, IL, OK, NC, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, WA, SD, VT, KS, NV, SC, FL, CA, NY, IN
- Insubstantial responses which don't give a definition (18): ME, ID, OK, NC, LA, TN, VA, MT, TX, WI, NJ, CO, VT, NV, FL, CA, NY, IN
- Total substantial responses (excludes blanks, NA, vague, undefined) (16): AL, IL, PA, MD, AZ, AK, SK, MO, AR, MI, MN, UT, WA, SD, KS, SC
- Type of definition:
    - Quantified binder content difference between cores (1 state): AL
    - Quantified gradation analysis between cores or differs from JMF (2): AL, PA
    - Quantified Density variation (e.g. nuclear gauge) (3): MO (TM-75), WA, KS
    - Ordinal scale of severity (e.g. Low, Medium High) (2): IL, SK
    - Vague or non-relevant answers (3): NC, LA, CA
    - NA (2): OK, NV
    - Not explicitly defined (13): ME, ID, TN, VA, MT, AZ, TX, WI, MO (survey response), NJ, VT, NY, IN (respondent goes on to mention separation of aggregates)
    - Separation/non-uniform distribution of aggregate particles (not specified otherwise, or "bad enough that we can see it" (UT)) (9): MD, AK, AR, UT, SD, SC, FL, LA, IN (in elaborating response after saying not defined)
    - Visual and thermal (2): CO, NC
    - PMTP (1): MN
    - Blank response (1): KY
- 7 states responded with specs/links – PA, AK, SK, MO, MN, WA, SC.
- 5 states have a solid definition: AL, PA, MO, WA, KS

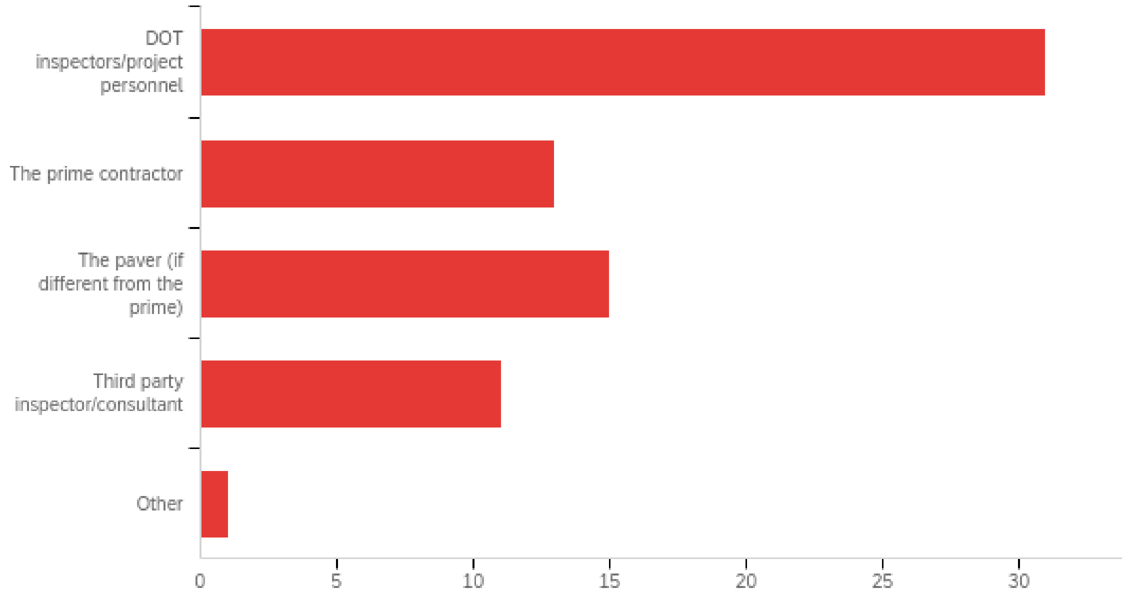
Table of responses:

State	How does your organization define segregation in AC pavement in its construction and materials specifications?
ME	Not defined
ID	We do not have a definition. That's a little unnerving.
AL	Unacceptable segregation of a hot and warm mix asphalt mat is defined as any area in which two six inch {150 mm} cores are taken and the average percent liquid asphalt binder content of the cores have an absolute difference greater than 0.50 percentage points of the design liquid asphalt binder content, or the combined gradation analysis of the two cores on selected sieves has an absolute difference greater than 10 percentage points from the job mix formula.
IL	Generally, segregation is defined as areas of non-uniform distribution of coarse and fine aggregate particles in the hot-mix asphalt pavement. Further, segregation can be broken down into End-of-Load Segregation (A systematic form of segregation typically identified by chevron-shaped segregated areas at either side of a lane of pavement, corresponding with the beginning and end of the truck load) and Longitudinal Segregation (a linear pattern of segregation that usually corresponds to a specific area of the paver). Segregation can be low, medium, or high severity. Low: A pattern of Segregation where the mastic is in place between the aggregate particles; however, there is slightly more coarse aggregate in comparison with the surrounding acceptable mat. Medium: A pattern of segregation that

	has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which exhibits some lack of mastic. High: A pattern of segregation what has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which contains little mastic.
OK	NA
NC	Aggregate segregation or Temperature segregation
LA	visual inspection; density variations
PA	Pattern Segregation. Pattern segregation is continuous or repeated areas of non-uniform distribution of coarse and fine aggregate particles in the finished mat. See current PennDOT Publication 408, Specifications, Section 413.3(h)3. Pattern Segregation (http://www.dot.state.pa.us/public/PubsForms/Publications/Pub_408/408_2020/408_2020_2/408_2020_2.pdf). The Pub. 408, Specifications also addresses Flushing. See link and Section 413.3(h)4. Flushing.
TN	Segregation is not explicitly defined in our Spec Book.
MD	separation of coarse aggregate particles
VA	Not have any specific difference with a norm since it is not a part of distresses in the Survey.
MT	We don't.
AZ	We don't specifically define the term segregation in our Specifications. We have the following general comment in all our different types of AC mixes: The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.
AK	Segregation in HMA is defined as the separation of the coarse aggregates in the mix from the rest of the mix. Visually the newly paved mat's surface has a rougher texture than the surrounding area. HMA segregation is addressed in our specs http://dot.alaska.gov/stwddes/dcsspecs/assets/pdf/hwyspecs/sshc2020.pdf) in the following sections: During the pre-paving meeting (Section 401-3.01 Pre-Paving Meeting). During compaction (Section 401-3.07 Asphalt Pavers) During storage (Section 401-3.14 Temporary Storage of HMA) Finished surface (Section 401-3.18 Surface Requirements and Tolerances)
TX	Not officially defined
SK	Segregation is defined within MoH End Product Specification for Asphalt Concrete – 4112: Segregation is defined as an area of the pavement where the texture differs visually from the texture of the surrounding pavement. For the purposes of classifying pavement segregation, only segregated areas greater than 0.1 m^2 and centre-of-paver streaks greater than 1 m in length will be considered. Moderate or severe segregated areas which do not meet these size parameters will be considered Surface Defects. Pavement segregation severity will be classified as follows: 1.2.1.20.1 Slight – The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding acceptable mix. Moderate – Significantly more stone than the surrounding mix; moderately segregated areas usually exhibit a lack of surrounding matrix. Severe – Appears as an area of very stony mix, stone against stone, with very little or no matrix. Centre-of-Paver Streak – Appears as a continuous or semi-continuous longitudinal "streak" typically located in the middle of the paver "mat".
WI	it is not defined
MO	The term 'segregation' is used throughout MoDOT's specifications, typically referring to the segregation of aggregates for use in concrete, asphalt, aggregate base, rock blanket or linings, and even in rock fill applications, but without official definition. Our Engineering Policy Guide (EPG) defines segregation in an asphalt mix as follows: Segregation is the separation of the aggregate in the mix resulting in areas with an undesirable gradation. See EPG discussion on segregation at: http://epg.modot.org/index.php/460.7_Mat_Problems#460.7.10_Segregation
AR	Segregation in asphalt concrete hot mix paving is the non-uniform distribution of aggregate that results in non-uniform surface texture.

MI	Areas of Bituminous Pavement exhibiting non-uniform distribution of coarse and fine aggregate particles that is visually identifiable or can be identified by other methods.
NJ	Segregation is not formerly defined in our specification but we consider pavements that are not mix well segregated.
CO	We evaluate segregation in two manners - visual and thermal
MN	Use of Paver Mounted Thermal Profiling AASHTO PP 80
UT	We do not have a definition for it as part of a standard acceptance procedure. If it is bad enough that we can see it then the Resident Engineer can reject the material and it is removed and replaced. Asphalt mix segregation has not been a problem with our 1/2 inch fine graded materials. We have eliminated 3/4 inch and above mixes.
WA	WSDOT Standard Specification Section 5-04.3(10)B HMA Compaction – Cyclic Density
SD	non uniform or variable surface texture
VT	Does not define segregation.
KS	It is defined by density change along a ~50 ft longitudinal nuclear density profile with readings spaced every 5 feet. The average minus the low reading must be less than or equal to 2.2 lb/cu ft and the high minus the low reading must be less than or equal to 4.4 lb/cu ft.
NV	N/A
SC	2007 Standard Specification - 401.4.28Defined as areas of non-uniform distribution of coarse and fine aggregate particles in a compacted HMA pavement.
FL	We are concerned with segregation which results in low in-place density.
CA	Presence of segregation (visual inspection) on fresh pavement surface.
KY	(no response)
NY	The specification mentions segregation but it is not defined.
IN	Not officially defined. Other guidance documents offer the following: Segregation occurs when the fine and coarse aggregates become separated from each other during the hauling or paving operation. Segregated mats feature locations where there are primarily coarse aggregate particles with no fines—the appearance is similar to an open graded mixture. There will be other locations within a segregated mat where there are few, if any, pieces of coarse aggregate and mainly consists of asphalt coated fines—appearing like a sand surface.

Q8 - Who has the contractual responsibility to determine if the asphalt is segregated? Choose all that apply.



#	Answer	%	Count	
1	DOT inspectors/project personnel	43.66%	31	ME, ID, AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, WA, VT, KS, NV, FL, CA, KY, NY
2	The prime contractor	18.31%	13	ME, IL, NC, TN, MD, VA, MT, TX, NJ, SC, KY, NY, IN
3	The paver (if different from the prime)	21.13%	15	ME, ID, LA, TN, MD, MT, TX, WI, MO, MN, SD, FL, KY, NY, IN
4	Third party inspector/consultant	15.49%	11	ME, ID, AL, NC, PA, TN, MD, TX, SK, FL, NY
5	Other	1.41%	1	ME
	Total	100%	71	

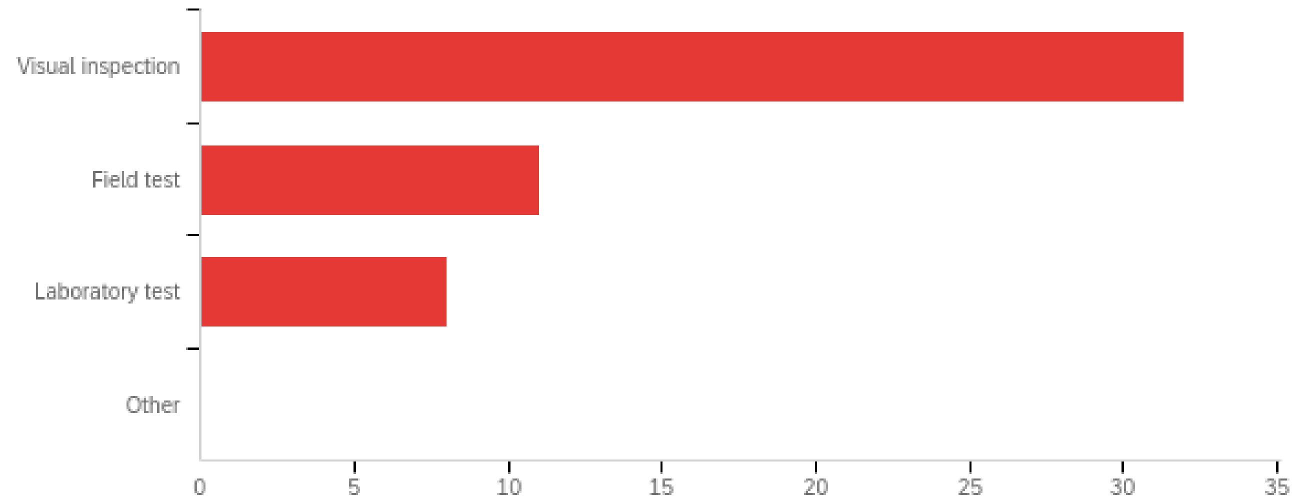
#	Answer	% of 35	Count	
1	DOT inspectors/project personnel	85.71%	31	ME, ID, AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, WA, VT, KS, NV, FL, CA, KY, NY
2	The prime contractor	37.14%	13	ME, IL, NC, TN, MD, VA, MT, TX, NJ, SC, KY, NY, IN
3	The paver (if different from the prime)	42.86%	15	ME, ID, LA, TN, MD, MT, TX, WI, MO, MN, SD, FL, KY, NY, IN
4	Third party inspector/consultant	31.43%	11	ME, ID, AL, NC, PA, TN, MD, TX, SK, FL, NY
5	Other (DOT construction support from central office)	2.86%	1	ME

Q9 - What other person has the contractual responsibility to determine asphalt segregation?

There was only one response, as only one state chose "other" for Q8

State	What are the acceptance criteria for visual inspection?
ME	DOT construction support from central office

Q10 - How does your organization determine segregation in the field at the time of construction? Choose all that apply



#	Answer	%	Count	
1	Visual inspection	62.96%	34	All but OK
2	Field test	20.37%	11	IL, NC, PA, TX, MO, MI, CO, MN, UT, WA, KS
3	Laboratory test	16.67%	9	ID, AL, IL, NC, PA, CO, UT, NV, FL
4	Other	0.00%	0	
	Total	100%	54	

#	Answer	% of 35	Count	
1	Visual inspection	97.14%	34	All but OK
2	Field test	28.57%	11	IL, NC, PA, TX, MO, MI, CO, MN, UT, WA, KS
3	Laboratory test	25.71%	9	ID, AL, IL, NC, PA, CO, UT, NV, FL
4	No answer	2.86%	1	OK

Q11 - What are the acceptance criteria for visual inspection?

- Total responses (excludes blanks): 29 (Only OK did not pick "Visual Inspection" on Q10)
- Insubstantial responses/no criteria/no visible segregation (22): ID, LA, TN, MD, VA, MT, AZ, AK, TX, WI, MO, NJ, MN, UT, WA, VT, KS, NV, SC, CA, NY, IN
- Substantial responses (7): IL, PA, SK, AR, MI, CO, FL
- Response type:
    - Not asked (1): OK
    - Blank ("(no response)") (5): ME, AL, NC, SD, KY
    - See Q7 response (definition) (1): IL (Ordinal scale mentioned)
    - Gradation difference between cores (1): CO
    - Restate definition (1): PA
    - Mention of/list of tests/measures without criteria (2): LA, FL
    - "No visible segregation" or like (8): TN, AZ, AK, TX, KS, CA, NY, IN
    - Uniform texture (3): MO, NJ, SC
    - Not in writing/not established (6): ID, MD, WI, UT, WA, AZ
    - NA (3): VA, VT, NV
    - "Undefined" (1): MT
    - Ordinal scale (Moderate, Severe, etc.) (2): IL, SK
    - Based on area of segregation (2): AR, MI
    - Engineer judgement (2): MN, AK
- 2 states replied with specs/links - PA, CO

Table of responses:

State	What are the acceptance criteria for visual inspection?
ME	(no response)
ID	As we don't have a definition within our spec book, that would be left to the construction staff and contractor to work through.
AL	(no response)
IL	See response in definition section above.
~~OK~~	
NC	(no response)
LA	Suspected segregation is subject to density verification, ride quality and permeability testing.
PA	Pattern Segregation. Pattern segregation is continuous or repeated areas of non-uniform distribution of coarse and fine aggregate particles in the finished mat. The Department will address pattern segregation as follows: 3.a Evaluating Pattern Segregation. If the Representative observes pattern segregation that may result in defective pavement, then: • The Inspector will notify the Contractor of the observed pattern segregation. • The Contractor may continue to work at their own risk while immediately and continually adjusting the operation to eliminate the pattern segregation from future work.
TN	No visible segregation.
MD	We do not have one in writing but if we were to do it, we would implement sand test method, which is similar to find the texture of milling surface.
VA	n/a

MT	Undefined
AZ	There is no acceptance criteria. Any AC showing signs of segregation is supposed to be removed and replaced.
AK	Typically the segregated surface is rougher than the surrounding areas. Training and experience of inspectors are key in detecting segregation.
TX	any visibly segregated areas
SK	Acceptance criteria is based on the severity of the segregation by visual inspection. The pavement will either be accepted, accepted with required repairs, or rejected and require replacement. Visual acceptance criteria are as follows: Moderate – Significantly more stone than the surrounding mix; moderately segregated areas usually exhibit a lack of surrounding matrix. Severe – Appears as an area of very stony mix, stone against stone, with very little or no matrix. Centre-of-Paver Streak – Appears as a continuous or semi-continuous longitudinal "streak" typically located in the middle of the paver "mat". Potential repairs include: For lower lifts: Slight, Moderate and Centre-of-Paver Streak Segregation on lower lifts will not require repair. Severe Segregation on lower lifts shall require a remove and replace repair unless otherwise approved by the Engineer. For top lift: Slight Segregation on top lift will not require repair. Moderate Segregation on top lift will require a Class II repair (approved slurry seal).
WI	not established
MO	Acceptable visual inspection would include uniform appearance of the mat, without irregularities in the surface of the mix.
AR	If a pattern of segregation develops, or if segregation occurs over a large area (3 square yards [3 sq m] or more), paving shall cease until the problem has been corrected. Visual inspection of the compacted pavement will be made to determine the extent of any segregation.
MI	The visual acceptance criteria for segregation is calculated by summing locations within the length required, which is greater than 215 square feet per 328 feet of lane length.
NJ	The criteria is looking for uniform texture and appearance in the pavement mat.
CO	See Section 401.16 of our specifications. https://www.codot.gov/business/designsupport/cdot-construction-specifications/2019-construction-specifications/2019-specs-book/2019-division-400
MN	Engineers judgement. THis only happens when no one in the field pays attention to the PMTP
UT	We don't have a specific visual inspection test.
WA	Visual Inspection is utilized to identify potential areas of segregation but is not a acceptance criteria for HMA
SD	(no response)
VT	NA
KS	If it is easily visible, there is an issue.
NV	N/A
SC	Visual observation by looking at the finished mat to be homogeneous - consistent in texture.
FL	First, a visual inspection of the pavement is made to identify segregated (or potentially segregated) areas. Then three 6" diameter cores are obtained in each

	"segregated" area and the cores are sent to the FDOT District lab for measurement of in-place density.
CA	Presence of mix segregation on the surface of fresh pavement.
KY	(no response)
NY	The pavement surface shall have no surface defects including segregation when paving is completed.
IN	HMA mixtures shall not exhibit segregation, flushing, or bleeding. Corrective action shall immediately be taken to prevent continuation of these conditions.

Q12 - What field tests are used to determine or measure segregation? Please provide link to or text of the test procedure(s) and/or specifications. Include tests on 1. surface/intermediate layer mixes with smaller aggregate and 2. asphalt/bituminous treated base mixes with larger aggregate.

- Total states with responses (9): IL, PA, TX, MO, MI, CO, MN, WA, KS
- Method – density gauge, sieve analysis, temperature (thermal or physical)
    - Not Asked (24): ME, ID, AL, OK, NC, LA, TN, MD, VA, MT, AZ, AK, SK, WI, AR, NJ, SD, VT, NV, SC, FL, CA, KY, NY, IN
    - Blank ("(no response)") (1): NC
    - Density Profile (1): TX
    - Nuclear density gauge (5): MO (none for base), WA, KS, TX, MI
    - Non-nuclear density gauge (1): TX
    - Sieve analysis (0):
    - Thermal camera (1): CO
    - Thermal imaging system (2): CO, MN (PMTP),
    - ROSAN V or other surface scanner (0):
    - Permeability test (1): IL
    - Surface macrotexture (1): PA
    - Core density and thickness (1): UT
- 9 states replied with specs/links - IL, PA, TX, MO, MI, CO, MN, WA, KS
- 11 states picked this choice in Q10 (NC and UT did not answer Q12 after selecting field test in Q10)

Table of responses:

State	What field tests are used to determine or measure segregation? Please provide link to or text of the test procedure(s) and/or specifications. Include tests on 1. surface/intermediate layer mixes with smaller aggregate and 2. asphalt/bituminous treated base mixes with larger aggregate.
~~ME~~	
~~ID~~	
~~AL~~	
IL	Although not often used to identify segregation, an after-the-fact investigative field permeability test can help identify difference in compaction levels of adjacent areas of the pavement. The link for the procedure is found in Appendix B.25 in the Manual of Test Procedures is given below. __https://idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Materials/Manual%20of%20Test%20Procedures%20for%20Materials%20 2020.pdf
~~OK~~	

NC	(no response)
~~LA~~	
PA	Comparison of the average depth of surface macrotexture between areas with pattern segregation and areas with non-segregated pavement according to PTM No. 751 (http://www.dot.state.pa.us/public/PubsForms/Publications/PUB_19/Pub%2019%20Ch%2011.pdf). The pattern segregation is unacceptable if the difference in average pavement texture depth between the non-segregated and segregated areas exceeds 0.024 inch. The difference of 0.024 inch is used for all pavement types (wearing, binder, & base courses).
~~TN~~	
~~MD~~	
~~VA~~	
~~MT~~	
~~AZ~~	
~~AK~~	
TX	Segregation (density profile) - Tex-207-F, Part V. Our specification requires this method for all layers of HMA. Test Procedure - https://ftp.txdot.gov/pub/txdot-info/cst/TMS/200-F_series/pdfs/bit207.pdf See Specification SS3077 - http://www.dot.state.tx.us/apps-cg/specs/ShowAll.asp?year=4&type=SS&number=3
~~SK~~	
~~WI~~	
MO	1) MoDOT Test Method TM 75 - Determining Segregation Using the Nuclear Density Gauge. https://epg.modot.org/index.php/106.3.2.75_TM-75,_Determining_Segregation_Using_the_Nuclear_Density_Gauge 2) The specification for asphalt/bituminous treated base mixes do not address segregation.
~~AR~~	
MI	Michigan Test Method (MTM) 326 https://www.michigan.gov/documents/mdot_MTM_CombinedManual_83501_7.pdf
~~NJ~~	
CO	CP 58 - Thermal Segregation https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-fmm/cps/CP-50s/29-cp-58-21
MN	All layers use PMTP on travelled lanes. http://www.dot.state.mn.us/materials/amt/specialprovisions.html
UT	We take 10 cores randomly per day for density and thickness. We also randomly test for binder content and gradation, at least 4 per day. Segregated spots can cause any of these to be out of specification. If this happens the mix is in penalty and can go into reject. If this happens the entire day's production will be removed and replaced. The contractor knows this could happen. With this incentive, they make sure they don't have segregated places. The contractor at that point does not have the option to just fix a segregated spot.
WA	WSDOT utilizes WSDOT SOP 733 Determination of Pavement Density Differentials Using the Nuclear Density Gauge
~~SD~~	
~~VT~~	

KS	Segregation check using the nuclear density gauge - http://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/Connections/ConstManual/2018/5.8.3._Segregation_Check_Nuke_Gauge.pdf
~~NV~~	
~~SC~~	
~~FL~~	
~~CA~~	
~~KY~~	
~~NY~~	
~~IN~~	

Q13 - What laboratory tests are used to determine or measure segregation?

Please provide link to or text of the test procedure(s) and/or specifications. Include tests on 1. surface/intermediate layer mixes with smaller aggregate and 2. asphalt/bituminous treated base mixes with larger aggregate.

- Total responses (8): ID, AL, IL, PA, CO, UT, NV, FL
- Substantial responses (6): ID, AL, IL, PA, CO, FL
- Tests:
  - Not Asked (26): ME, ID, AL, OK, LA, TN, MD, VA, MT, AZ, AK, SK, WI, AR, NJ, SD, VT, NV, SC, FL, CA, KY, NY, IN
  - Blank ("(no response)") (1): NC
  - Core density (3): ID, FL, PA
  - Aggregate gradation or sieve analysis from core (6): ID, CO, IL, AL, PA, NV
  - Binder content (3): ID, AL, PA
  - No specific test (1): UT
- 4 states replied with specs/links - AL, PA, CO, FL
- 8 states picked this choice in Q10 (NC did not answer Q13 after selecting lab test in Q10)

Table of responses:

State	What laboratory tests are used to determine or measure segregation? Please provide link to or text of the test procedure(s) and/or specifications. Include tests on 1. surface/intermediate layer mixes with smaller aggregate and 2. asphalt/bituminous treated base mixes with larger aggregate.
~~ME~~	
ID	Nothing formal. We are trying to monitor relationships between primary (#4) sieve, asphalt binder content, and Gmm by plotting lab values from samples against production quantities.
AL	All testing shall be in accordance with ALDOT-389, "Evaluation of Segregated Areas in Hot Mix Asphalt Pavement." The location of all cores taken for segregation evaluation will be determined by the Department. https://www.dot.state.al.us/mtweb/Testing/testing_manual/pdf/Pro/ALDOT389.pdf
IL	Although not a typical, standard procedure for Segregation identification and control, an after-the-fact investigative extraction and gradation analysis to compare adjacent pavement areas could be performed to quantify the degree of segregation present.
~~OK~~	

NC	(no response)
~~LA~~	
PA	Gradation, asphalt content, and pavement density laboratory tests are used to determine if the pattern segregation is defective and the segregated pavement should be removed and replaced. The specific specification language is: 3.c Defective Pavement. At locations selected by the Inspector and with the Inspector present, drill a minimum of three 6-inch diameter cores from the area of pattern segregation and a minimum of three cores from the pavement representing a non-segregated area. Do not compress, bend, or distort samples during cutting and handling and immediately provide the cores to the Inspector. The Inspector will transport cores to the producer’s laboratory. With the Inspector present, test the cores at the plant for density, asphalt content, and gradation. The Department may request additional tests as part of its evaluation of pattern segregation. Determine the maximum theoretical density according to Bulletin 27, the core density according to PTM No. 715, and asphalt content according to PTM No. 757 if previously identified problematic aggregates are used in the mixture, PTM No. 702 modified Method D, and PTM No. 739 or other test method identified in the producer QC Plan. An area of pattern segregation contains defective pavement if the summation of absolute deviations from any two sieves is 20% or more from the JMF, the core density is defective, the mixture is defective in asphalt content, or the mixture is defective for percent passing the 75 µm (No. 200) sieve. Remove and replace the full width of the affected lane and a minimum of 5 feet beyond each end of the area with unacceptable pattern segregation. Construct replacement pavement conforming to the appropriate surface tolerances as specified in Section 313.3(l) or Section 413.3(l). Links/References: PTM Nos. (http://www.dot.state.pa.us/public/PubsForms/Publications/PUB_19/Pub%2019%20Ch%2011.pdf) Reference to Bulletin 27 for maximum theoretical density - Bulletin 27 references AASHTO T 209 with some exceptions to delete some apparatus from use (plastic vacuum bowls, vacuum flask for mass determination in air, plastic pycnometers, and water aspirator), to specify Test Method A - Mechanical Agitation, to revise conditioning time to 2 h +/- 5 min (non-absorptive coarse aggregate - <=1.5% as determined by AASHTO T 85) or to 6 h +/- 5 min (absorptive coarse aggregate - >1.5% as determined by AASHTO T 85), and to revise conditioning temperature by grade of binder (PG58S-28 = 140 +/- 3 C, PG 64S-22 = 145 +/- 3C, and PG64E-22 = 153 +/- 3C).
~~TN~~	
~~MD~~	
~~VA~~	
~~MT~~	
~~AZ~~	
~~AK~~	
~~TX~~	
~~SK~~	
~~WI~~	
~~MO~~	
~~AR~~	
~~MI~~	
~~NJ~~	
CO	CP 46 - Determination of the gradation of aggregate from a core, see Section 401.16 of the specifications for determining segregation criteria. https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-fmm/cps/CP-50s/29-cp-58-21
~~MN~~	
UT	We don't have any tests designed just for segregation.
~~WA~~	
~~SD~~	

~~VT~~	
~~KS~~	
NV	Sieve analysis
~~SC~~	
FL	Three 6" diameter cores are obtained in each "segregated" area and the cores are sent to the FDOT District lab for measurement of in-place density. A standard Gmb test is performed. FM 1-T 166 is used and the CoreDry, or equivalent, vacuum drying device is mandatory. The Gmm of the mix as determined for the sublot of material in which the cores came from is used to calculate and average %Gmm of the three cores. The value must be greater than or equal to 89.5%.
~~CA~~	
~~KY~~	
~~NY~~	
~~IN~~	

Q14 - Please describe the other method(s) used to determine or measure AC segregation and any text of or links to any relevant procedures, specifications, and acceptance criteria.

There were no responses to this question. No state selected “other” for Question 10.

Q15 - How is segregation in asphalt concrete remedied when it is encountered?

- Total responses: 33 (all except ME, NC)
- Blank ("(no response)") (2): ME, NC
- Certify/inspect equipment (1): IL
- Suspend work to address cause (7): AL, IL, PA, TX, MI, SD, KS
- Remove and Replace (19): OK, LA, PA, MD ("should be repaved"), MT, AZ, TX, SK, MO, AR, NJ, CO, UT, WA, VT, NV, CA, FL, NY
- Corrective action (repair) (5): AL, SK (slurry seal), KS, SC, NY
- Use MTD (3): MI, NJ (MTV required), KY
- Fog Seal (1): CA
- Chip Seal (2): MN (in the past), KS
- Microsurfacing has been used (1): WI
- "Reject" (2): TN, IN
- Cost deduction (4): ID, AR, TX (no bonus pay), WA
- No specific remedy (2): MD, VA
- 8 states replied with specs/links – AL, IL, AK, AR, MI, CO, KY, IN

Table of responses:

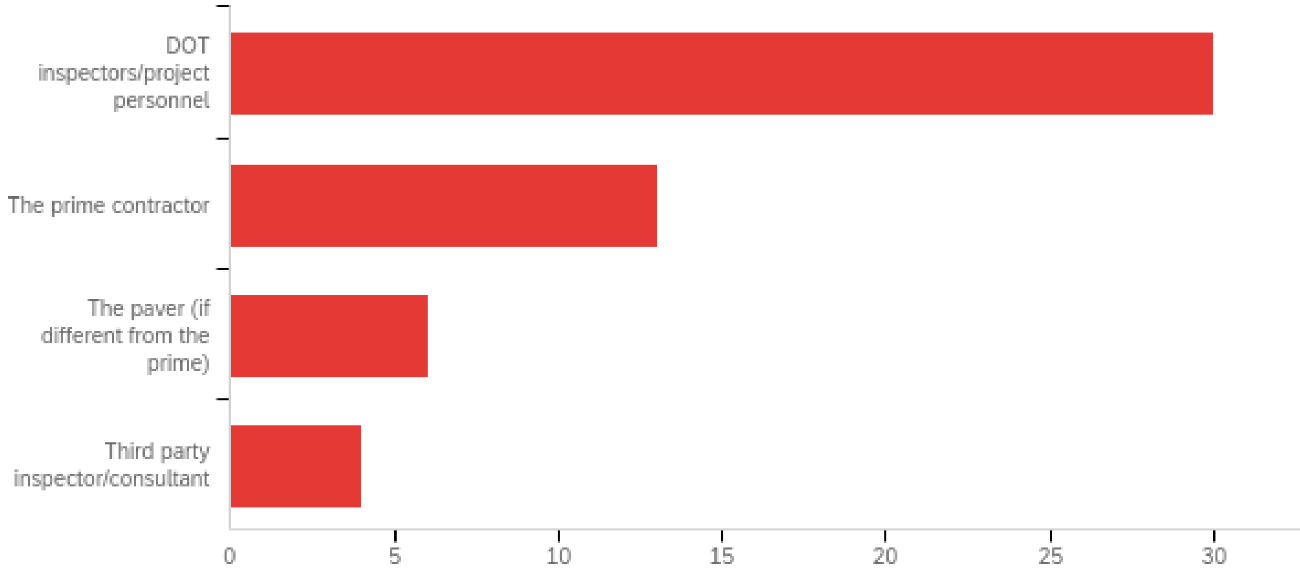
State	How is segregation in asphalt concrete remedied when it is encountered?
ME	(no response)
ID	We have no contractual remedy beyond impacts in the Contractor's pay factors (VMA, Air Voids, Mainline Density)
AL	All coring and traffic control required by ALDOT-389 shall be conducted/supplied by the Contractor at no cost to the Department; however, the Contractor will be reimbursed $500.00 per core when core results are within tolerances and the coring operations require additional traffic control. At any time that segregation is determined to be unacceptable, work shall be automatically suspended if positive corrective action is not taken by the Contractor to prevent further segregation in the mat. Upon suspension, the Contractor shall place a test section not to exceed 500 tons {500 metric tons} of the affected mixture for evaluation by the Engineer. However, if after a few loads it is apparent that the corrective actions were not adequate, work shall again be suspended and the segregated areas evaluated in accordance with ALDOT-389. Likewise, if after 500 tons {500 metric tons} it is apparent that the problem has been solved, work will be allowed to continue.
IL	The in-place HMA shall be evaluated daily for segregation according to the QC/QC document "Segregation Control of Hot-Mix Asphalt" in Appendix B.20 of the Manual of Test Procedures (link given above in Q12) It is important to understand the causes of segregation in HMA and to prevent segregation from occurring as much as possible so that a remedy is generally not needed. Segregation can occur from improper aggregate stockpile formation as well as when surge silos with HMA. Haul trucks need to be loaded correctly from the silo to prevent/reduce segregation in the trucks. Temperature segregation can occur in the trucks during long hauls, especially if the truck is not sufficiently insulated or tarped. Segregation can result from improper design of MTD and paver hopper inserts and from excessively emptying the amount of mix in the hopper between trucks. The distribution system in front of the paver screed shall have chain curtains, deflector plates, and/or other devices designed and built by the paver manufacturer to prevent segregation during distribution of the mixture from the hopper to the paver screed. The Contractor shall submit a written certification that the devices recommended by the paver manufacturer to prevent segregation have been installed and are operational. Prior to paving, the Contractor, in the presence of the Engineer, shall visually inspect paver parts specifically identified by the manufacturer's check list for excessive wear and the need for replacement. The Contractor shall supply the completed check list to the Engineer noting the condition of the parts. Worn parts shall be replaced.

	The Engineer may require additional inspection prior to placement of the surface course or at other times throughout the work. The Contractor's Annual Quality Control Plan or Addendum shall identify the individual(s) responsible for performing and documenting the daily evaluations. Quality Control Plans and Addendums for subsequent projects shall reflect the corrective actions taken, whether the corrective action was initiated by the Contractor or the Engineer.________If segregation of a sufficient degree is encountered during paving the Contractor will be required to correct the cause. Dialogue should occur between the Contractor and the Engineer. If the cause cannot be determined or corrected, the paving operation can be shut down by the Engineer until the problem has been remedied.
OK	If severe enough Remove and Replace
NC	(no response)
LA	if found to be a significant durability concern, remove and replace.
PA	If areas of pattern segregation are determined to be defective, then the pattern segregation pavement areas are removed and replaced (full width and a minimum 5 feet beyond each end of the area with unacceptable pattern segregation). Otherwise, nothing is done except if pattern segregation is unacceptable by macrotexture test comparison, the Contractor is required to stop paving operations immediately, evaluate cause of pattern segregation, and propose corrective actions for review by Dept. Representative and for authorization from Dept. Representative to resume paving.
TN	Reject
MD	If it is found in significant amount, the section should be repaved. But nothing in present specs.
VA	No specific. Case by Case, but can be rejected based on Spec language. maybe conduct testing (gradation).
MT	Removed and replaced.
AZ	Removing and replacing the affected area.
AK	Remedial measures would have been discussed with Contractor in the pre-paving meeting. Measures may include remove and replace, or covering segregated areas with sealant (e.g, joint sealant + sand, or GSB-78 /88 …).
TX	TxDOT ultimately pays for material based on the Air Voids. However, if you have a failing placement test such as Segregation Density Profile, you are not eligible for any bonus pay. If the sublot is removed and replaced, the sublot can then be eligible for bonus pay (assuming all spec items are met on the replaced section). Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if two consecutive density profiles fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.
SK	Potential repairs include: For lower lifts: Slight, Moderate and Centre-of-Paver Streak Segregation on lower lifts will not require repair. Severe Segregation on lower lifts shall require a remove and replace repair unless otherwise approved by the Engineer. For top lift: Slight Segregation on top lift will not require repair. Moderate Segregation on top lift will require a Class II repair (approved slurry seal).
WI	there are rarely noticeably segregated areas due to the fine graded mixes used but treatments such as microsurfacing has been used to correct.
MO	Remove and replace.
AR	If any of the test results do not meet the requirements, the area/areas will be considered non-complying. If the non-complying material is deemed reasonably acceptable according to Subsection 105.04, it may be left in place at a reduced cost to the Department. In the event the material is found unacceptable relative to segregation

	and it is determined that the material must be removed, the area(s) of segregation shall be removed full depth of the course paved. Replacement of the material by dumping and spreading by hand or motor grader will be permitted on base and binder courses for areas less than 50 linear feet (15 m) in length. Replacement of larger areas of base and binder and replacement of any surface course will be accomplished with a paver. On surface course, the minimum area to be removed shall be 50 linear feet (15 m) of the full width of the mat paved.
MI	Segregation severity will be determined in accordance with MTM 326. If segregation thresholds are met twice on a paving course, the Contractor may be required to use a Material Transfer Device for the remaining paving for that course at no additional cost to the Department. The Contractor shall implement corrective actions immediately and report them to the Engineer before the next day's paving begins. The Contractor shall also provide, in writing, the actions that will be taken to eliminate segregation . The Contractor, with the Engineer, shall closely monitor the in-place pavement when paving resumes. If, once paving resumes, heavy segregation is identified, the Contractor shall stop production and a complete evaluation of the manufacturing and paving process shall be completed. This evaluation shall follow the troubleshooting guide and suggested changes according to the equipment manufacturer's recommendations or the guide manual AASHTO Segregation Causes and Cures for Hot Mix Asphalt. Areas identified as heavy segregation by the MDOTMBITSEG2 computer program do not meet the Departments acceptance criteria for HMA pavement and full removal and replacement is required in these areas.
NJ	MTV is required on all asphalt projects so we do not see much segregation but if it does occur that area will be milled out and replaced.
CO	Generally remove and replace - see Section 401.16 of our specifications.
MN	In the past, we might require a chip seal full width.
UT	See the above explanation. A segregated spot could cause the entire day's production to be removed and replaced. This may be why we don't have significant segregation problems.
WA	The Standard Specifications allow a $500 Cyclic Density Price Adjustment will be assessed for any 500-foot section with two or more density readings below 90 percent of the theoretical maximum density. Alternately removal and replacement by the contractor is an option is the contractor choses or the HMA could be rejected if the pay factor is below 0.75.
SD	find cause and correct to get uniform surface texture
VT	Remove and replace.
KS	If it is minor in extent but detrimental to the intended life or function of the road, the segregated area will be sealed (hand methods) or patched. If the segregation is extensive and detrimental, a chip seal is usually placed. Typically the contractor is shut down and has to adjust their operation when segregation checks fail (see segregation check procedure), so we don't see a lot of extensive segregation.
NV	Remove and replace
SC	Depending on the overall severity, type of mix, road conditions, and amount of traffic. Base and Intermediate mixes can be milled and repaired and cut out 10 feet on either side, surface course often require up to 300 feet on either side to get a good smooth patch for the final riding surface. If its a minor defect, we prefer for the contractor to fix it prior to compacting it when under the same traffic control.
FL	If the test value described above is less than 89.5% Gmm, then the material must be removed and replace 50 ft. either side of the segregation, though this is sometimes shortened depending on the localized situation.

CA	Ranges from fog sealing to remove and replace.
KY	403.03.04 in the Kentucky Specifications for Road and Bridge Construction outlines how to load the material. An MTV is used on larger projects and could be used on others if segregation is an issue. Also, the mix may be altered or the loading pattern at the plant may be changed.
NY	If it is isolated then the area is repaired. If it is at the end of every load (end of load segregation), the contractor may have remove and replace the entire lane rather than fixing all these segregated areas which will look like a quilt.
IN	Segregated, flushed, or bleeding HMA mixtures will be referred to the Department's Division of Materials and Tests for adjudication as a failed material in accordance with 105.03.

Q16 - Who has the contractual responsibility to determine the applicable remedy and determine if it has been implemented? Choose all that apply.

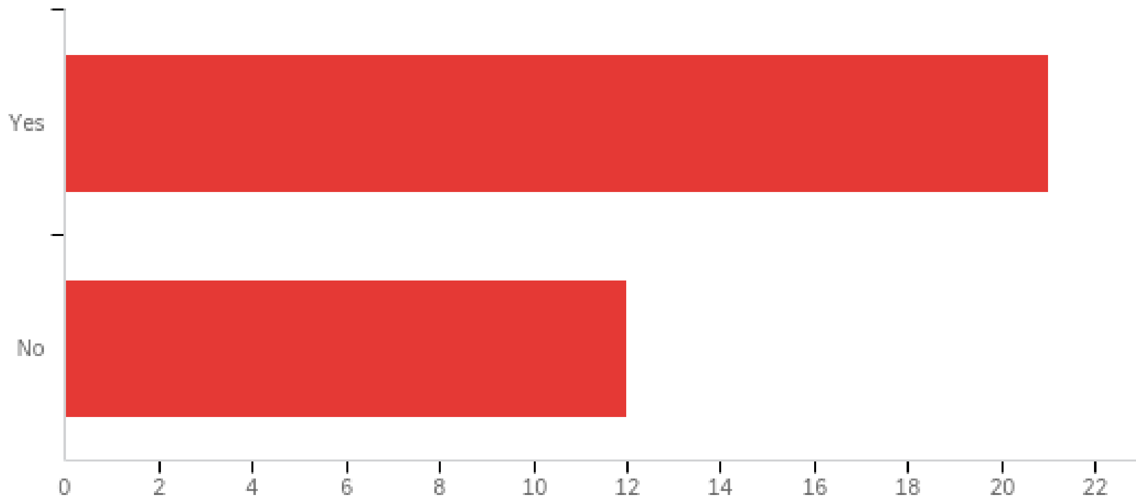


#	Answer	%	Count	
1	DOT inspectors/project personnel	55.36%	31	ID, AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, SD, VT, KS, NV, SC, FL, CA, KY, NY
2	The prime contractor	25.00%	14	ID, IL, PA, VA, AZ, TX, WI, NJ, UT, WA, KS, SC, KY, IN
3	The paver (if different from the prime)	10.71%	6	PA, TX, WI, UT, CA, KY
4	Third party inspector/consultant	8.93%	5	ID, PA, AZ, SK, UT
	Total	100%	56	

ME and NC did not respond to this question

#	Answer	% of 35	Count	
1	DOT inspectors/project personnel	88.57%	31	ID, AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, SD, VT, KS, NV, SC, FL, CA, KY, NY
2	The prime contractor	40.00%	14	ID, IL, PA, VA, AZ, TX, WI, NJ, UT, WA, KS, SC, KY, IN
3	The paver (if different from the prime)	17.14%	6	PA, TX, WI, UT, CA, KY
4	Third party inspector/consultant	14.29%	5	ID, PA, AZ, SK, UT
	No answer	5.71%	2	ME, NC

Q17 - Is there a process through which the contractor can object to or appeal the Agency-required remedy?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is there a process through which the contractor can object to or appeal the Agency-required remedy?	1.00	2.00	1.36	0.48	0.23	33

#	Answer	%	Count	
1	Yes	63.64%	21	ID, AL, LA, VA, MT, AZ, WI, MO, AR, MI, NJ, Co, MN, UT, WA, VT, KS, FL, CA, NY, IN
2	No	36.36%	12	IL, OK, PA, TN, MD, AK, TX, SK, SD, NV, SC, KY
	Total	100%	33	

ME and NC did not respond to this question

#	Answer	% of 35	Count	
1	Yes	60.00%	21	ID, AL, LA, VA, MT, AZ, WI, MO, AR, MI, NJ, Co, MN, UT, WA, VT, KS, FL, CA, NY, IN
2	No	34.29%	12	IL, OK, PA, TN, MD, AK, TX, SK, SD, NV, SC, KY
	No answer	5.71%	2	ME, NC

Q18 - Briefly describe the process for a contractor to appeal an Agency-required remedy.

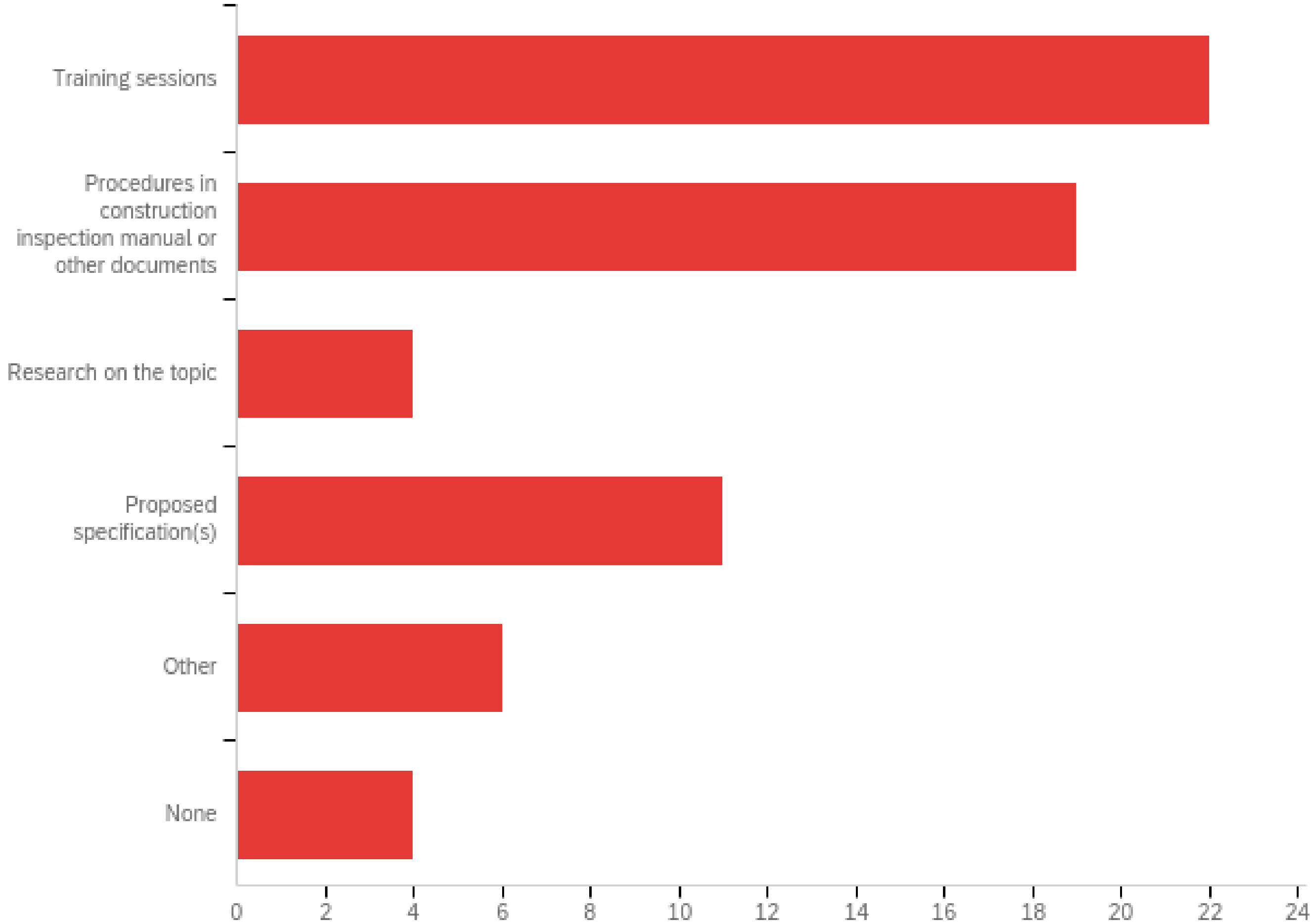
- Not Asked (12): ME, IL, OK, NC, PA, TN, MD, AK, TX, SK, SD, NV, SC, KY
- Blank ("(no response)") (2): ME, NC
- File a claim/follow claims procedure (15): AL, VA, WI, MO, AR, NJ, CO, MN, WA, VT, KS, FL, CA, NY, IN
- Work with engineer (6): LA, VA, NJ, MI, KS, CA
- Engineering Analysis (2): AZ, UT
- Use density gauge (2): MO, WA
- Collect cores (3): WA, VT, CA
- "We don't really have a required remedy" (1): ID

Table of responses:

State	Briefly describe the process for a contractor to appeal an Agency-required remedy.
ME	(no response)
ID	We don't really have a required remedy.
AL	File a NOI to file a claim. Meet to resolve the issue w/o claim.
~~IL~~	
~~OK~~	
NC	(no response)
LA	Work with the project engineer and chief construction engineer to offer solutions
~~PA~~	
~~TN~~	
~~MD~~	
VA	If they don't reach to the agreement, then Contractor can file a claim (Notice of intent to File a Claim first). Just as other things.
MT	Claim
AZ	It is through what we call and Engineering Analysis (EA), as follows: The proposal shall contain an engineering analysis of the anticipated performance of the asphaltic concrete if left t in place. The engineering analysis shall also detail any proposed corrective action, and the anticipated effect of such corrective act ion on the performance. The engineering analysis shall be performed by a professional engineer experienced in asphaltic concrete testing and the development of asphaltic concrete mix designs.
~~AK~~	
~~TX~~	
~~SK~~	
WI	they must proceed through the claims process
MO	The density gauge (nuclear or non-nuclear) may be used in accordance with MoDOT Test Method TM-75 to solve disputes with the contractor over the existence of segregation. Otherwise, conflict resolution procedures will be followed.
AR	Should a dispute not be resolved by the written decision of the Resident Engineer, subsequent appeal by the Contractor shall be submitted in writing within 60 calendar days of the decision of the Resident Engineer, and shall be addressed directly to the Chief Engineer.
MI	The Contractor determines the corrective action plan. The Department Engineer either approves or disapproves of the proposed plan.
NJ	The contractor will give a written appeal to the Resident Engineer. SME's will have their internal discussion and if they disagree with the contractor and neither party is willing to budge it goes through our claims process.
CO	The Contractor can submit a dispute and follow the processes outlined in Section 105.22 of our specifications.

	https://www.codot.gov/business/designsupport/cdot-construction-specifications/2019-construction-specifications/2019-specs-book/2019-division-100
MN	file a claim
UT	The contractor puts together an engineering analysis describing why the material should remain in place, or what they plan to do for the correction.
WA	The contractor can challenge the test results taken by density gauge and cores would be taken to verify the density reading.
~~SD~~	
VT	An accurate description of a deviation from specified materials, a fair assessment of the value of the final product or material and a clear process to promote prompt resolution. Following the Acceptance Decision, the Contractor may request that the appropriate Agency Bureau Director mediate the dispute. If no agreement on the validity of the combined information (i.e. Owner and Contractor supplied) is reached, a referee sample may be sent to an independent laboratory for testing. If the Contractor is aggrieved by the decision of the Director, the Contractor may appeal the decision as allowed for in their contract with the Agency.
KS	The Contractor must propose a repair that is acceptable to the Engineer. If the Engineer does not approve the proposed repair and requests a new proposal, then that decision may be appealed. Standard contract claim appeal procedures are followed.
~~NV~~	
~~SC~~	
FL	For any construction situation, the contractor can escalate an issue higher and higher up through the FDOT chain of command. Additionally, there is a process called the Dispute Review Board, which sort of acts like an FDOT court, but this is not used too often.
CA	DOT marks segregated location(s) and informs Contractor. Cores from suspected may be taken and tested for aggregate gradation to confirm segregation. Impacted materials is rejected for out of specification. Engineer request Contractor for remedies of rejected materials. Mutually agreed to remedies ranges from financial deduction, to applying fog seal, to remove and replace. Contractor has to option to inform Engineer to bring any dispute to dispute resolution board (DRB).
~~KY~~	
NY	Dispute process. This is in the specification where contractor has the right to dispute any additional work performed.
IN	Failed material decisions are routed thru the Failed Materials Committee (FMC). After an initial adjudication, the contractor is afforded one appeal, if they so choose. They can present further evidence, make their case and try to persuade the FMC why the original decision is not correct. We can either uphold the appeal or deny it.

Q19 - What internal steps has your organization taken to address segregation? Choose all that apply.



#	Answer	%	Count	
1	Training sessions	33.33%	22	ID, AL, IL, LA, PA, TN, MT, AK, TX, SK, WI, MO, AR, MI, CO, WA, SD, KS, SC, FL, NY, IN
2	Procedures in construction inspection manual or other documents	28.79%	19	IL, LA, PA, WI, MO, MI, CO, MN, WA, SD, VT, KS, NV, SC, FL, CA, KY, NY, IN
3	Research on the topic	6.06%	4	IL, LA, MI, FL,
4	Proposed specification(s)	16.67%	11	IL, LA, PA, TX, MI, VT, KS, NV, SC, FL, IN
5	Other	9.09%	6	ID, TN, VA, SK, NJ, SD
6	None	6.06%	4	OK, MD, AZ, UT
	Total	100%	66	

ME and NC did not respond to this question

#	Answer	% of 35	Count	
1	Training sessions	62.86%	22	ID, AL, IL, LA, PA, TN, MT, AK, TX, SK, WI, MO, AR, MI, CO, WA, SD, KS, SC, FL, NY, IN

2	Procedures in construction inspection manual or other documents	54.29%	19	IL, LA, PA, WI, MO, MI, CO, MN, WA, SD, VT, KS, NV, SC, FL, CA, KY, NY, IN
3	Research on the topic	11.43%	4	IL, LA, MI, FL,
4	Proposed specification(s)	31.43%	11	IL, LA, PA, TX, MI, VT, KS, NV, SC, FL, IN
5	Other	17.14%	6	ID, TN, VA, SK, NJ, SD
6	None	11.43%	4	OK, MD, AZ, UT
	No answer	5.71%	2	ME, NC

Q20 - Please describe the other internal step(s) taken to address segregation

- Only the 6 states that chose "Other" in Q19 answered this:
- MTD (2): TN, NJ
- We don't have segregation problem (1): VA
- Prepare Surface Inspection Guide (1): SK
- Training and certification (2): ID, SD
- Communicate problem to subject matter experts in house (1): ID

Table of responses:

State	Please describe the other internal step(s) taken to address segregation
ID	Provide more training to construction staff. Communicate the problem to our subject matter experts in house.
TN	We require by spec. the use of MTD (Shuttle buggy) for all asphalt mixes except scratch paving. This seems to have gone a long way into solving the issue. In training we teach to always load trucks from the silo in 3 small dumps.
VA	We don't have much of issues with segregation.
SK	The Ministry has created a Surface Inspection Guide to assist in the uniform identification of segregation severity. The guide contains descriptions and example images of segregation with varying severity.
NJ	We require and MTV on all asphalt paving projects.
SD	addressed during training and certification classes

Q21 - Please provide a link to or text of any other relevant documents (e.g. inspection manual, research report) regarding asphalt segregation.

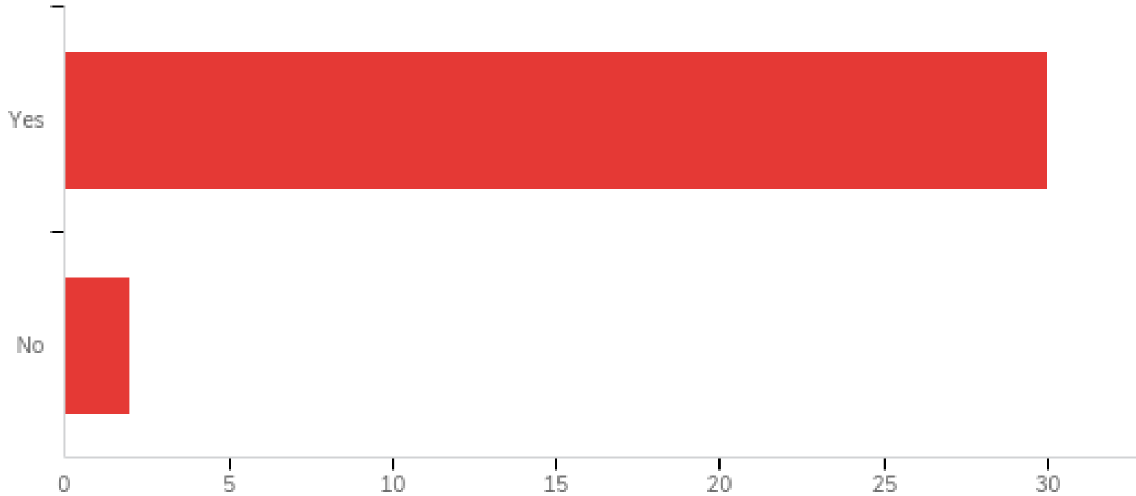
- 18 states provided spec info or links – IL, MT, AZ, AK, TX, *SK*, WI, MO, CO, MN, WA, VT, KS, SC, CA, KY, NY, IN
- Blank ("(no response)") (15): ME, ID, AL, OK, NC, LA, PA, TN, VA, AR, MI, NJ, SD, NV, FL (Note that some of these states included links or spec numbers in responses to preceding questions: AL, PA, AR, MI, FL, UT)
- "Do not have any now" (1): MD
- "We do not have any reports on segregation" (1): UT
- "We don't have any internal documents and rely on the Asphalt Institute MS-22 manual" (1): MT
- "The Surface Inspection Guide has not been published yet." (1): SK. (Thus a document exists but is not yet available.)
- Link to entire spec book, perhaps with instruction to search for "segregation" (6): IL, WI, CO, WA, VT, KY
- Link to entire spec book, with section or page number or link to specific section (7): AZ, AK, TX, MO, CA, NY, IN
- Link to materials test book (1): MN
- Link to test procedure (1): TX
- Link to other document ("Segregation Check Points") (1): KS

Table of responses:

State	Please provide a link to or text of any other relevant documents (e.g. inspection manual, research report) regarding asphalt segregation.
ME	(no response)
ID	(no response)
AL	(no response)
IL	http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Construction/Standard-Specifications/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202016.pdf
OK	(no response)
NC	(no response)
LA	(no response)
PA	(no response)
TN	(no response)
MD	Do not have any now.
VA	(no response)
MT	We don't have any internal documents and rely on the Asphalt Institutes MS-22 manual.
AZ	https://azdot.gov/sites/default/files/media/2019/11/2008-standards-specifications-for-road-and-bridge-construction.pdf 417-6 Construction Requirements Pg. 416
AK	Section 401 of specs http://dot.alaska.gov/stwddes/dcsspecs/assets/pdf/hwyspecs/sshc2020.pdf
TX	Test procedure - Tex-207-F, Part V: https://ftp.txdot.gov/pub/txdot-info/cst/TMS/200-F_series/pdfs/bit207.pdf Specification-SS3077: http://www.dot.state.tx.us/apps-cg/specs/ShowAll.asp?year=4&type=SS&number=3 Within our specification, we have an entire section on segregation density profiles. Perform Ctrl+f to search for "segregation".
SK	The Surface Inspection Guide has not been published yet.
WI	Standard Specification https://wisconsindot.gov/rdwy/stndspec/ss-04-50.pdf Construction and Materials Manual https://wisconsindot.gov/rdwy/cmm/cm-04-59.pdf

MO	http://epg.modot.org/index.php/460.6_Paving_Operations http://epg.modot.org/index.php/460.7_Mat_Problems
AR	(no response)
MI	(no response)
NJ	(no response)
CO	Use the link below and enter the search term "segregation" https://cse.google.com/cse?cx=006660347502177050818:oztywyig2nq
MN	http://www.dot.state.mn.us/materials/amt/index.html
UT	We don't have any reports on segregation.
WA	The WSDOT Standard Specifications, Construction Manual and Materials Manual are available at: https://wsdot.wa.gov/publications/manuals/default.htm
SD	(no response)
VT	https://outside.vermont.gov/agency/VTRANS/external/docs/construction/2018%20Construction%20Manual%20Addendum.pdf https://outside.vermont.gov/agency/VTRANS/external/docs/construction/02ConstrServ/PreContract/2018SpecBook/2018%20Standard%20Specifications%20for%20Construction.pdf
KS	Segregation check points - https://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=8880852
NV	(no response)
SC	https://www.scdot.org/business/pdf/constructionManual/Division%20400.pdf
FL	(no response)
CA	Refer to Sections 39-2.01C(2), “Spreading and Compacting Equipment,” and 39-2.01C(15)(b), “Method Compaction” of the Standard Specifications for additional compaction equipment requirements and for Type A HMA to Sections 39-2.02C, “Construction,” and for RHMA-G, 39- 2.03C, “Construction,” of the Standard Specifications, for detailed compaction temperature and coverage requirements. Be sure to: • Inspect the finished HMA surface for marks, tearing, and irregular texture that may be caused by segregated mix. Notify the contractor of any defective areas.
KY	https://transportation.ky.gov/Construction/Pages/Kentucky-Standard-Specifications.aspx
NY	See page 402-18. https://www.dot.ny.gov/main/business-center/contractors/construction-division/construction-repository/murk1b_cim.pdf
IN	https://www.in.gov/dot/div/contracts/standards/GIFE/GIFEMaster.pdf page 13-13

Q22 - If the need arises for the researchers to contact you for further information/clarifications, are you willing to respond to inquiries?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If the need arises for the researchers to contact you for further information/ clarifications, are you willing to respond to inquiries?	1.00	2.00	1.06	0.24	0.06	32

#	Answer	%	Count	
1	Yes	93.75%	30	ID, AL, IL, OK, LA, PA, TN, MD, MT, AZ, AK, TX, SK, WI, MO, AR, MI, NJ, CO, MN, UT, SD, VT, KS, SC, FL, CA, KY, NY, IN
2	No	6.25%	2	NV, VA
	Total	100%	32	

Answered “No”: NV, VA
No answer: ME, WA, NC

Alabama

SECTION 410 ASPHALT PAVEMENTS
410.06 Correction of Deficiencies and Defects.

Deficiencies in surface smoothness as determined in Subarticle 410.05(a) shall be remedied to the extent practicable by rolling while the material is still workable. Otherwise the layer shall be removed and replaced as necessary to obtain required smoothness. "Skin patching" of a surface layer to correct low areas or heating and scraping to correct high areas will not be permitted. Overlays of not less than 80 pounds per square yard {45 kg/m^2} may be authorized by the Engineer for surface smoothness deficiencies provided all material in the overlay is without additional cost to the Department.

Deficiencies in thickness shall be remedied as specified in Item 410.03(f)1.

All areas containing excessive or deficient amounts of liquid asphalt binder, all areas showing unacceptable segregation of materials, and all areas unbonded after rolling shall be removed and replaced at no cost to the Department. Unacceptable segregation of a hot and warm mix asphalt mat is defined as any area in which two six inch {150 mm} cores are taken and the average percent liquid asphalt binder content of the cores have an absolute difference greater than 0.50 percentage points of the design liquid asphalt binder content, or the combined gradation analysis of the two cores on selected sieves has an absolute difference greater than 10 percentage points from the job mix formula. All testing shall be in accordance with ALDOT-389, "Evaluation of Segregated Areas in Hot Mix Asphalt Pavement." The location of all cores taken for segregation evaluation will be determined by the Department. All coring and traffic control required by ALDOT-389 shall be conducted/supplied by the Contractor at no cost to the Department; however, the Contractor will be reimbursed $500.00 per core when core results are within tolerances and the coring operations require additional traffic control.

At any time that segregation is determined to be unacceptable, work shall be automatically suspended if positive corrective action is not taken by the Contractor to prevent further segregation in the mat. Upon suspension, the Contractor shall place a test section not to exceed 500 tons {500 metric tons} of the affected mixture for evaluation by the Engineer. However, if after a few loads it is apparent that the corrective actions were not adequate, work shall again be suspended and the segregated areas evaluated in accordance with ALDOT-389. Likewise, if after 500 tons {500 metric tons} it is apparent that the problem has been solved, work will be allowed to continue.

When correcting subsurface mixtures (base and binder layers), the removal and replacement may be limited to the actual defective areas or the full mat width within the limits of individual defective areas as directed by the Engineer. Removal and replacement of hot and warm mix asphalt wearing surface layers shall be a minimum of the full mat width and 10 feet {3 m} in length. All surface tolerance requirements shall apply to the corrected areas for both subsurface and surface mixes.

Areas found deficient in density shall be removed and replaced or immediately re-rolled until density is acceptable.

All work specified in this Article shall be performed without additional compensation.

Q13 response from survey: All testing shall be in accordance with ALDOT-389, "Evaluation of Segregated Areas in Hot Mix Asphalt Pavement." The location of all cores taken for segregation evaluation will be determined by the Department. https://www.dot.state.al.us/mtweb/Testing/testing_manual/pdf/Pro/ALDOT389.pdf

ALDOT-389-98

EVALUATION OF SEGREGATED AREAS IN HOT-MIX ASPHALT PAVEMENT

1. Scope

1.1 The objective of this procedure is to identify areas of unacceptable segregation in hot-mix (HMA) pavements and to determine the segregation acceptability parameters. Segregation in HMA pavement is the non-uniform distribution of coarse and fine aggregates within the finished HMA mat. Close visual inspection of the mat is critical in order to detect and locate areas of segregation.

1.2 This procedure evaluates segregation of HMA pavements by testing the asphalt content and the gradation analysis of 6 in (150 mm) diameter cores taken as a result of visual determination of suspected segregated areas. The asphalt content and gradation analysis of the core will be used in determining deviations from the Job Mix Formula (JMF) and specification tolerances.

2. Referenced Documents

2.1. Alabama Department of Transportation Standard Specifications for Highway Construction.

2.1.1. Section 410, Hot-Mix Asphalt Pavements.

2.1.2. Section 327, Plant Mix Bituminous Base and PATB

2.1.3. Section 420, Polymer Modified Open Graded Friction Course

2.1.4. Section 423, Stone Matrix Asphalt (SMA)

2.1.5. Section 424, Superpave Bituminous Concrete Base, Binder, and Wearing Surface Layers

2.2. Alabama Department of Transportation Testing Manual.

2.2.1. ALDOT-258, Mechanical Analysis of Extracted Aggregates.

2.3. AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing

2.3.1. AASHTO T 30, Standard Method of Test for Mechanical Analysis of Extracted Aggregate.

2.3.2. AASHTO T 308, Standard Method of Test for Determining the Asphalt Binder Content of Hot-Mix Asphalt (HMA) by the Ignition Method.

3. Determination of Segregated Test Location and Core Cutting

3.1. Segregation may be present in isolated areas or may be in continuous longitudinal strips along the roadway. All areas either suspected of having segregation or obviously segregated shall be marked and referred for testing. Coarse and fine areas shall be marked separately. No random number will be used for test site location for segregation due to segregation being a visual observance.

3.2. The Contractor shall core as soon as possible after mat compaction, as directed by the Engineer, but prior to covering with an overlying layer, or, in the case of the wearing surface layer, upon completion of the hot-mix pay items. Two cores shall be taken at each chosen location for further testing.

3.3. For isolated marked areas, select the two most segregated spots (points), which are at no less than 20 in (0.5m) apart, and extract one core at each point.

3.4. For continuous longitudinal strips, select the two most segregated spots (points) within an area no longer than 150ft (50 m) section, and extract one core at each point.

3.5. Cores shall be taken through the entire layer to be tested. The layer to be tested shall be separated from other layers by sawing or other suitable means. The Department will take immediate possession of the segregated cores for further testing.
3.6. Allow the pavement to cool before coring. Ice may be used to accelerate cooling before coring. Care shall be taken to avoid stress or damage to the core interface during coring, handling, or transporting. Identify each core specimen with a paint pen or keel.
3.7. The Department's certified technician will determine the core location.

4. Evaluation Process

4.1. Segregated areas will be evaluated by comparing the percent asphalt content and gradation analysis of two cores to the design criteria found on the JMF.
4.2. All testing of the cores shall be performed by certified Department technicians in the division laboratory using an ignition oven, sieves and sieve shaker. Department testing may be witnessed by the Contractor's certified technicians.
4.3. The percent asphalt content of the two cores shall be determined in accordance with AASHTO T 308. Once the asphalt content has been determined, obtain a gradation analysis of the extracted aggregates as per ALDOT 258 and AASHTO T 30. Aggregates from both cores shall be combined before performing the gradation analysis.
4.4. Compute the deviation between the percent asphalt content of the cores to the design percent asphalt content from the JMF. Average the two deviations. If the average deviation is in excess of ± 0.50 percent from the design amount, then the area is considered to be segregated.
4.5. Determine the maximum size aggregate used in the mix from the JMF. Refer to Table I to determine the sieves to use in the evaluation process.

Table I

Determination of Sieves Utilized In Segregation Evaluation	
Maximum Size Aggregate	**Sieves Utilized**
1.5 in (37.5 mm)	½ in and No. 4 (12.5 mm and 4.75 mm)
1.0 in (25.0 mm)	3/8 in and No. 4 (9.5 mm and 4.75 mm)
¾ in (19.0 mm)	No. 4 and No. 8 (4.75 mm and 2.36 mm)
½ in (12.5 mm)	No. 8 (2.36 mm)
3/8 in (9.5 mm)*	No. 8(2.36 mm)

*with up to 5% retained on the 1/2" {12.5 mm}

4.6. Compare the gradation of the selected sieves to the design gradation from the JMF. If the deviation for either sieve is in excess of ±10 percent from the design gradation, the area is considered segregated.
4.7. If either asphalt content or gradation analysis of any selected sieves are determined to exceed the allowable tolerances, the area will be considered segregated.

5.0 REPORT

5.1 The following information shall be included on a report for each segregated area or section. See figure 1 for a sample report form.
5.1.1 Project Number and County
5.1.2 Production lot and date produced
5.1.3 Location of cores (station and offset) and description of area (including pictures)
5.1.4 Copy of Approved JMF
5.1.5 Percent Asphalt Content from JMF (A)
5.1.6 Percent Asphalt Content as determined by the Ignition Oven Testing (B)
5.1.7 Average Deviation of Core Percent Asphalt Content to Percent Asphalt Content from JMF

5.1.8 Maximum Aggregate Size and Selected Sieves Utilized
5.1.9 Gradation Analysis of Combined Cores on Select Sieves
5.1.10 JMF Percent Passing Selected Sieves
5.1.11 Deviation of the combined Gradation Analysis of the two Cores on Selected Sieves to the Percent Passing from JMF
5.1.12 Signatures of Certified Technicians performing the tests

Figure 1

Segregation Evaluation Report

Copies:
District Engineer
Project Engineer
File

Project Number: ________________
County: ____________________
Date: ______________________

Layer Tested: ______________ Layer Thickness: ____________ Date Placed: _______________

Evaluation Site Information	
Production Lot Number	
Location of Evaluation Site (Station)	
Location of Evaluation Site (Offset)	

Detailed description of area: (include pictures of area) ____

____

____

____

Figure 1

Asphalt Content Evaluation		
Design % AC [A]		
% AC of Core 1 / Core 2		
Average % AC of Cores [B]		
Absolute Difference between Average % AC of Cores and Design % AC* [A-B]		

* Allowable Tolerance = ±0.50% Maximum

Gradation Analysis Information		
Input the Selected Sieve Sizes	mm	mm
Design Percent Passing (JMF)		
Sample Gradation % Passing		
Deviation between Sample and Design % Passing**		

** Allowable Tolerance = ±10% Maximum (Each Sieve)

Contractor Certified Technician Signature & Expiration Date of Certification

ALDOT Certified Technician Signature & Expiration Date of Certification

Alaska

Q7 response: Segregation in HMA is defined as the separation of the coarse aggregates in the mix from the rest of the mix. Visually the newly paved mat's surface has a rougher texture than the surrounding area. HMA segregation is addressed in our specs http://dot.alaska.gov/stwddes/dcsspecs/assets/pdf/hwyspecs/sshc2020.pdf) in the following sections: During the pre-paving meeting (Section 401-3.01 Pre-Paving Meeting). During compaction (Section 401-3.07 Asphalt Pavers) During storage (Section 401-3.14 Temporary Storage of HMA) Finished surface (Section 401-3.18 Surface Requirements and Tolerances)

DIVISION 400–ASPHALT PAVEMENTS AND SURFACE TREATMENTS
SECTION 401 HOT MIX ASPHALT PAVEMENT

CONSTRUCTION REQUIREMENTS

401-3.01 PRE-PAVING MEETING. Meet with the Engineer for a pre-paving meeting in the presence of project superintendent and paving foreman at least five (5) working days before beginning paving operations. Submit a paving plan and pavement inspection plan (per 401-3.20) at the meeting.

Include the following elements in the paving plan and address these elements at the meeting:

1. Sequence of operations
2. List of equipment that will be used for production, transport, pick-up (if applicable), laydown, and compaction
3. Summary of plant modifications (if applicable) for production of WMA
4. Procedures to produce consistent HMA
5. Procedures to minimize material and thermal segregation
6. Procedures to minimize premature cooling
7. Procedures to achieve HMA density
8. Procedures for joint construction including corrective action for joints that do not meet surface tolerance requirements

. . . .

401-3.07 ASPHALT PAVERS. Use self-propelled asphalt pavers with heated vibratory screed assemblies to spread and finish HMA to the specified section widths and thicknesses without introducing thermal or material segregation.

Equip the paver with a receiving hopper having sufficient capacity for a uniform spreading operation and a distribution system to place the HMA uniformly in front of screed. Use a screed assembly that produces a finished surface of the required smoothness, thickness and texture without tearing, shoving or displacing the HMA. Heat and vibrate screed extensions. Place auger extensions within 20 inches of the screed extensions or per written manufacturer's recommendations. SECTION 401

Equip the paver with a means of preventing segregation of the coarse aggregate particles from the remainder of the HMA when carried from the paver hopper back to the augers.

Equip the paver with automatic screed controls capable of operating from a reference line or a ski from either or both sides of the paver.

The use of a "Layton Box" or equivalent towed paver is allowed on bike paths, sidewalks, and driveways.

401-3.14 TEMPORARY STORAGE OF HMA. Silo type storage bins may be used, provided the characteristics of the HMA remain unaltered.

Signs of visible segregation, heat loss, changes from the JMD, change in the characteristics of asphalt binder, lumpiness, and stiffness of the mixture, are causes for rejection.

Do not store HMA on barges.

401-3.18 SURFACE REQUIREMENTS AND TOLERANCES. The finished surface of all HMA paving must match dimensions shown in the contract for horizontal alignment and width, profile grade and elevation, crown slope, and pavement thickness. Water must drain across the pavement surface without ponding. The surface must have a uniform texture, without ridges, puddles, humps, depressions, and roller marks. The surface must not exhibit raveling, cracking, tearing, asphalt bleeding, or aggregate segregation. Leave no foreign material, uncoated aggregate or oversize aggregate on the HMA surface.

The Engineer will test the finished surface after final rolling at selected locations using a 10-foot straightedge. Measurements will include spanning joints. The Engineer will identify pavement areas that deviate more than 3/16 inch from the straightedge, including joints, as defective work. Perform corrective work by removing and replacing, grinding, cold milling or infrared heating such areas as required. Do not surface patch. After the Contractor performs corrective work, the Engineer will retest the area.

From Alaska Asphalt pavement Inspector's Manual
http://www.dot.state.ak.us/stwddes/desmaterials/assets/pdf/aphlt_insp_man/asphalt_inspect_man.pdf

p. 3-8:
3. Materials

Aggregates Proper stockpiling is the responsibility of the contractor. The stockpile site must be cleared and leveled prior to stockpiling. Stockpiles of different materials should be kept separate to prevent contamination. If you observe improper stockpiling, inform the contractor and the project engineer. Stockpiling is discussed in Airport Specifications 501-4.5 and Highway Specifications 305.

Poor stockpiling techniques result in larger particles rolling to the bottom of the stockpile, leaving the fines behind. This separation of different sizes is called segregation. Segregation results in out-of-specification asphalt concrete (some with too much large aggregate, some with too little). Both types result in weak pavement that will deteriorate rapidly.

It is the inspector's responsibility to watch for and report segregation any time the aggregate is handled or moved. Stockpiles should be built in layers to prevent segregation. Specifications allow only rubber-tired equipment on stockpiles. Steel tracked equipment will crush the aggregate, causing excess fines, failing tests, and inferior pavement.

p. 3-10
3.4. The 0.45 Power Chart
The shape of the curve connecting the plotted points indicates some properties of the mix. If it crosses the maximum density line, the mix is "gap graded" and will tend to segregate. A hump in the fine sand portion (#40 to #80 sieve) may indicate a "tender" mix, which is hard to handle, difficult to compact, and may be too soft after it cools.

p. 4-5
4.3. Proper Plant Operation
4.3.2 Stockpiling
A good mix will not come out of a plant if the aggregates going into it are bad. Many problems in mix production can be traced back to the cold aggregate. Even if good material comes out of the crusher, bad material will go into the cold bins if aggregate becomes contaminated or segregated during stockpiling or cold bin loading. Proper stockpiling is discussed in Section 4.2.

p. 4-7
4.3.9 Hot Mix Storage and Loading
Hot mix conveyors should have scrapers to prevent carryover (belt drippings). Segregation is the biggest problem in storage and loading. It can be minimized during silo loading by baffles or batching mechanisms. Trucks should be loaded by dumping the mix in a series of overlapping

heaps. Dribbling or flinging the mix when loading either silos or trucks leads to segregation and should be avoided.
(The remaining items of Section 4.3 apply only to batch plants)
Segregation in a silo is more likely if it is completely emptied several times during a shift. Use of a strain gauge bin level indicator is desirable since most high/low bin indicators are unreliable. It is desirable to keep the silo one-third to two-thirds full. Cooling is a problem if the mix is held too long in a silo, especially if the amount of mix is small or the silo is not insulated.

p. 6-1
6. Laydown
6.1. Responsibilities and Authority of the Laydown Inspector
6.1.1 Areas of Responsibility
You will always share responsibility for the quality of the paving mix. A materials inspector does the density and asphalt content tests on the pavement, but you must make sure these are being done as required. The plant inspector is responsible for seeing that good mix leaves the plant, but you must be alert to the mix quality too. Mix can become too segregated, cold, or contaminated after it leaves the plant. Materials testing is discussed in Chapter 3 of this manual; plant inspection is discussed in Chapter 4.

p. 6-3
6.1.2 Records
Production Checklist (During Paving)
• No visible segregation or contamination

p. 6-8
6.2. Equipment
6.2.3 Pickup Machines
Some contractors use belly dump trucks, which dump hot mix in windrows on the grade. Then a pickup machine (also called a windrow elevator) is used to deposit the mix into the paver. The windrows of hot mix must be the right size and in the correct location to give the proper spread without segregation.
A skilled dump man is important to good windrowing. He must tell the truck drivers where to start dumping and how fast to drive, and know when and if to adjust the truck gate widths.
Windrows tend to segregate in their long direction, with too much coarse material at the end. Long, thin windrows that overlap help compensate for the lineal segregation. Windrow length is a function of vehicle speed and belly gate width.
Windrowed asphalt concrete cools rapidly. You must carefully monitor the temperature of the windrows. If they are cooling too rapidly the contractor may have to hold the mix in the trucks longer and slow plant production. Overheating the asphalt at the plant is not an acceptable solution to this problem.
The pickup machine must pickup pick up as much asphalt concrete as possible. Paving mix left on the existing surface cools faster than the rest of the mix and may result in an area with low density. It may also leave a strip of segregated mix along each edge of the windrow.

p. 6-10
6.3. Placement
Coarse aggregate tends to roll to the tailgate of a truck. Trucks should be unloaded in a surge, which minimizes this potential cause of segregation.

Keeping the paver's hopper partially full at all times also reduces the potential for segregation. Any coarse aggregate, which rolls to the tailgate of a truck, drops into the hopper first. If the hopper is empty the coarse aggregate will all be fed to the screed at the same time. A line of coarse (segregated) material across the mat will result. If the hopper is partially full the coarse aggregate tends to mix back in with the rest of the asphalt concrete.

The paver should place the mix wherever possible. If it must be placed by hand, it should be shoveled to the required location. Flinging the mix with a shovel or raking it for long distances causes segregation. Surface tolerance and segregation require special care whenever pavement is placed by hand.

p. 6-19

6.7. Inspecting the Finished Mat

It takes some experience to judge the appearance of a finished mat, but some problems are obvious. The texture of the mat should be uniform; that is, there should be no sign of segregation or raveling. There should not be pieces of wood, large stones, or other contamination in the mat, nor should there be "fat" (oily) spots or bleeding. There should be no cracking (checking) or tearing of the mat. The Troubleshooting Guide (Appendix A) lists these and other common problems to look for, along with the most probable causes of them.

Defective areas of pavement must be marked, cut out, and replaced by the contractor. These patched areas, however, are almost never as high in quality as a pavement that is mixed and placed correctly in the first place.

Most defects in the finished mat can be avoided by careful inspection of the production and placement processes. Correcting defects is also easier the earlier in the process they are detected. If a consistent mix is produced, the pavement is placed in a dry weather on a firm base, and a good rolling pattern is established and followed, there should be no problem achieving required density. With good quality control, there should be no segregated or contaminated areas to be cut out and replaced. If the base is good and joints are properly built, the surface smoothness should be within tolerance.

p. 6-21

Figure 6-14 Segregation Visible in the Finished Mat

p. 8-1

8. Appendix A: Troubleshooting Guide

8.1. Hot-Mix Asphalt Pavements

8.1.1. Preface Working with hot-mix pavement is an art, not a science. The answer to every hot-mix problem cannot be found solely in a series of charts. However, the following information, coupled with common sense, experience, and communication between the producer and project owner will provide guidance for resolving most hot-mix problems.

p. 8-2

8.2. Possible Causes of Deficiencies in Plant-Mix Pavements

Problems with asphalt mixture / Types of deficiencies that may be	Poor quality aggregate	Aggregate too wet	Inadequate bunker separation	Aggregate feed gates not properly set	Over-rated drier capacity	Drier set too steep	Improper drier operation	Temperature indicator out of adjustment	Aggregate temperatures too high	Worn out screens	Faulty screen operation	Bin overflows not functioning	Leaky bins	Segregation of aggregates in bins	Carryover in bins due to overloading screens	Aggregate scales out of adjustment	Improper weighing	Feed of mineral filler not uniform	Insufficient aggregates in hot bins	Improper weighing sequence	Insufficient asphalt	Too much asphalt	Faulty distribution of asphalt to aggregates	Asphalt scales out of adjustment	Asphalt Meter out of adjustment	Undersize or oversize batch	Mixing time not uniform	Improperly set or worn paddles	Faulty dump gate	Asphalt and aggregate feed not synchronized	Occasional dust shakedown in bins	Irregular plant operation	Faulty sampling
Mixture appears dull in truck							A	A	A												A											A	
Mixture steams in truck	A	A			A	A	A	A																								A	
Mixture smokes in truck							A	A	A																							A	
Mixture too fat																B	B	A	A			A	A	B	C	B				C		A	
Mixture too brown or gray		A			A	A	A	A			A										A			B	C	B				C		A	
Mixture Burned				A			A	A	A																							A	
Mixture flattens in truck																						A	A	B	C	B				C		A	
Mixture in truck fat on one side																				B			A			B	B	A				A	
Mixture in truck not uniform											A	A	A	A	A	B	B	A	A	B			A	B	C		B	A	B	C	A	A	
Large aggregate uncoated	A				A	A	A	A													A		A	B	C	B	B	A		C		A	
Free dust on mix in truck	A	A																		B									B				
Free asphalt on mix in truck																B	B					A	A	B	C	B		A		C			
Truck weights do not check batch weights													B			B	B			B						B							
Uniform Temperatures difficult to maintain		A			A	A	A	A																								A	
Excess fines in mix	A		A	A							A	A	A	A	A	B	B	A	A							B	B			C	A		A
Agg. Grad. doesn't check job mix formula	A		A	A						A	A	A	A	A	A	B	B	A	A							B		A	A	C	A		A
Asphalt cont. doesn't check job mix formula	A			A												B	B				A	A	A	B	C	B	B	A		C			A

A = Applies to batch and drum-mix facilities B = Applies to batch facilities C = Applies to drum-mix plant facilities

8. Appendix A. Troubleshooting Guide 8-2 Asphalt Pavement Inspector's Manual
Revised January 2003

8.4. Mat Problem Troubleshooting Guide

Mat problems	Cold mix temperature	Variation of mix temperature	Moisture in mix	Mix segregation	Improper mix design (asphalt)	Improper mix design (aggregate)	Parking roller on hot mat	Reversing or turning too fast of rollers	Improper rolling operation	Improper base preparation	Truck holding brakes	Trucks bumping finisher	Improper mat thickness for maximum aggregate size	Improper joint overlap	Sitting long period between loads	Grade reference inadequate	Grade control wand bouncing on reference	Grade control hunting (sensitivity too high)	Grade control mounted incorrectly	Vibrators running too slow	Screed extensions installed incorrectly	Screed starting blocks too short	Incorrect nulling of screed	Kicker screws worn out or mounted incorrectly	Feeder gates set incorrectly	Running hopper empty between loads	Moldboard on strikeoff too low	Cold screed	Screed plates not tight	Screed plates worn out or warped	Screed riding on lift cylinders	Excessive play in screed mechanical connection	Overcorrecting thickness control screws	Too little lead crown in screed	Too much lead crown in screed	Finisher speed too fast	Feeder screws overloaded	Fluctuating head of material
Poor mix compaction	X	X	X		X	X	X	X	X	X																												
Roller marks		X					X	X	X	X																												
Bleeding or fat spots in mat		X	X		X	X																																
Mat shoving under roller		X	X		X	X		X	X	X																												
Transverse Cracking (checking)		X	X		X	X			X	X																												
Poor transverse joint	X								X													+	+						+		+	+					+	
Poor longitudinal joint	X								X					+			+	+	+												+		+				+	+
Poor precompaction	X									X			X							+											+					+		
Auger shadows				X	X	X																															+	
Screed not responding to correction	X	X											X						+										+		+	+				+		
Screed marks											X	X								+	+											+						
Mat texture-nonuniform	X	X		X	X	X				X			X		+						+					+		+	+	+	+					+	+	+
Tearing of mat—outside streaks	X																								+		+	+		+					+			
Tearing of mat—center streak	X																							+	+			+		+				+				
Tearing of mat—full width	X	X	X	X	X	X							X															+		+						+		
Wavy surface—long waves		X		X			X	X		X	X	X			+	+			+						+	+					+	+	+				+	+
Wavy surface—short waves (ripples)		X		X	X	X			X	X						+	+	+	+										+		+	+				+	+	+

Causes

Find the problem above. 2. +'s indicate causes related to the paver. X's indicate other problems to be investigated. Note: Many times a problem can be caused by more than one item, therefore, it is important that each cause listed is eliminated to ensure solving the problem.

8.5. Causes of Imperfections in Finished Pavements

Types of pavement imperfections / Possible causes of imperfections in	Insufficient or non-uniform tack coat	Improperly cured prime or tack	Mixture too coarse	Excess fines in mixture	Insufficient asphalt	Excess asphalt	Improperly proportioned mixture	Unsatisfactory batches in load	Excess moisture in mixture	Mixture too hot or burned	Mixture too cold	Poor spreader operation	Spreader in poor condition	Inadequate rolling	Rolling at the wrong time	Over-rolling	Rolling mixture when too hot	Rolling mixture when too cold	Roller standing on hot pavement	Overweight rollers	Roller vibration	Unstable base course	Excessive moisture in subsoil	Excessive prime coat or tack coat	Poor handwork behind spreader	Excessive hand raking	Labor careless or unskilled	Excessive segregation in laying	Faulty allowance for compaction	Operating finishing machine too fast	Mix laid in too thick course	Traffic put on mix while too hot
Bleeding						X	X	X																X								
Brown, dead appearance					X				X	X																						
Rich or fat spots						X	X	X																X				X				
Poor surface texture			X	X			X	X			X	X	X	X	X	X	X	X							X	X	X	X		X		
Rough uneven surface	X	X	X				X	X			X	X	X	X	X		X	X	X	X	X	X			X	X	X	X		X		
Honeycomb or raveling			X		X		X	X			X	X	X	X	X			X							X	X	X	X				
Uneven joints			X								X	X	X	X	X		X	X				X			X	X	X	X	X			
Roller marks				X		X	X				X			X	X		X	X	X	X							X					
Pushing or waves	X	X		X		X	X	X	X			X	X		X		X			X	X	X				X					X	X
Cracking (many fine cracks)				X	X		X								X	X	X			X		X	X									
Cracking (large long cracks)																X				X		X	X									
Rocks broken by roller			X				X				X	X	X		X	X	X			X												
Tearing of surface during laying			X		X		X			X	X	X	X									X						X		X		
Surface slipping on base	X	X		X		X	X		X		X			X	X	X		X		X		X	X	X								

8.8. Pavement Distress, Possible Causes and Rehabilitation Alternatives

Type of Distress	Possible Causes	Rehabilitation Alternatives
Longitudinal Cracking	Load Associated Structural deficiency Excessive air voids in Hot Mix Asphalt Concrete Asphalt cement properties Stripping of asphalt from aggregate Aggregate Gradation Construction deficiencies Non Load Associated Volume change potential of foundation soil Slope stability of fill materials Settlement of fill or in-place materials as a result of increased loading Segregation due to laydown machine Poor joint Construction Other construction deficiencies	Crack sealing Seal coat (applied to areas with cracking) Replacement (dig-out and replace distressed areas) Thin overlay with special treatment to seal cracks and minimize reflection cracking Asphalt-rubber membrane with aggregate seal or thin overlay Heater-scarification with a thin overlay

11. Appendix D: Random Sampling of Construction Materials (From Alaska DOT&PF Sampling Module)
p. 11-3
11.7. Examples of Straight Random Sampling Procedures Using Random Numbers
Sampling from a Stockpile: AASHTO T 2 recommends against sampling from stockpiles. However, some agencies use random procedures in determining sampling locations from a stockpile. Bear in mind that stockpiles are prone to segregation and that a sample obtained from a stockpile may not be representative. Refer to WAQTC FOP for AASHTO T 2 for guidance on how to sample from a stockpile.

12. Appendix E: Asphalt Glossary
p. 12-13
Segregation: The separation of the coarse and fine aggregate particles in an asphalt mix. The segregation of the mix can occur at several locations during the mix production, hauling, and placing operation. Some mixes are more prone to segregate than others. Asphalt mixes that have large top-size coarse aggregates (1 inch or greater), low asphalt cement contents, and are gap graded will segregate more readily when handled than a dense-graded mix of optimum asphalt content and a smaller top-size coarse aggregate. Segregation lessens pavement durability by increasing the air void content of the mix, which increases the potential for moisture damage. Segregated locations are susceptible to raveling and, if bad enough, to disintegration under traffic.

Single Surface Treatments: A single application of asphalt to any kind of road surface followed immediately by a single layer of aggregate of uniform size. The thickness of the treatment is about the same as the nominal maximum-size aggregate particles. A single surface treatment is a wearing and water-proofing course. The following is a list of SSTs:

> **High-Float Asphalt Surface Treatment**: A single-shot asphalt surface treatment where one application of high float emulsion is applied to the prepared surface followed by a single application of crushed gravel cover coat. The gradation of cover coat aggregate used in high-float emulsion surface treatments are typically similar to those used for crushed aggregate base course (D-1), except with 100 percent passing the ¾-inch sieve rather than the 100 percent passing the 1-inch sieve as with D-1. The fine aggregates allowed in high-float operations may cause segregation of larger materials and blockage in the chip spreader if they are not very dry. Therefore, maintain strict moisture content control of cover coat

materials. High-float asphalt surface treatments are more easily constructed in areas with dry climates, such as Interior Alaska. In the Yukon, high-float asphalt surface treatments are called “BST.”

13. Appendix F: Further Reading

National Asphalt Pavement Association, 5100 Forbes Blvd., Lantham, MD 20706; (301) 731-4748:

• Hot-Mix Asphalt Segregation: Causes and Cures

Alberta

Alberta

Transportation

SEGREGATION RATING MANUAL

2017

SEGREGATION RATING MANUAL

Introduction

This Segregation Rating Manual is a revision of earlier editions prepared by the Department. This document is intended to promote uniform specification interpretation leading to fair and consistent application. Information within this document is intended to supplement but not override specification requirements. The information in this manual reflects the current Standard Specifications for Highway Construction, Edition 15. The user is reminded to review contract documents as future specification revisions may not be captured in this document.

This manual has been prepared to help the user recognize the type and the severity of segregated areas on asphalt concrete pavement projects with updated reference photographs of segregated sites contained within Appendix A.

Questions and comments may be directed to the Pavement Engineering Section of the Technical Services Branch.

Pavement Engineering Section
Technical Services Branch
October, 2017

1.0 SEGREGATION INSPECTION PROCESS

The segregation inspection and classification process is described in the Standard Specifications 3.50 Asphalt Concrete Pavement (ACP) and 3.53 Asphalt Concrete Pavement – Superpave. This manual is not intended to repeat those specifications but to provide field staff with sample photographs of sites with different segregation severities along with examples of obvious defects.

The standard specifications also describe how segregation payment adjustments (i.e. penalties/bonuses) are to be calculated.

2.0 CLASSIFYING SEGREGATION SEVERITY

For the purposes of classifying pavement segregation, only segregated areas greater than 0.1m^2 and Centre-of-Paver streaks greater than 1 m in length are considered.

Slight Segregation - The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding acceptable mix.

Moderate Segregation - Significantly more stone than the surrounding mix; moderately segregated areas usually exhibit a lack of surrounding matrix.

Severe Segregation - Appears as an area of very stony mix, stone against stone, with very little or no matrix.

Centre-of-Paver Streak - Appears as a continuous or semi-continuous longitudinal "streak" typically located in the middle of the paver "mat".

Obvious Defect - Moderate or severely segregated areas which do not meet the size parameters above. Other items that are considered Obvious Defects are areas of excess or insufficient asphalt, improper matching of longitudinal or transverse joints, roller marks, tire marks, cracking or tearing, improperly repaired core holes, etc.

Blemish - A term not defined within the standard specifications but used by some to describe a pavement texture which is not yet considered to be slight segregation (i.e. segregation requirements do not apply).

As demonstrated in Figure 1, segregation severity is a continuum, and the transition between categories is not exact.

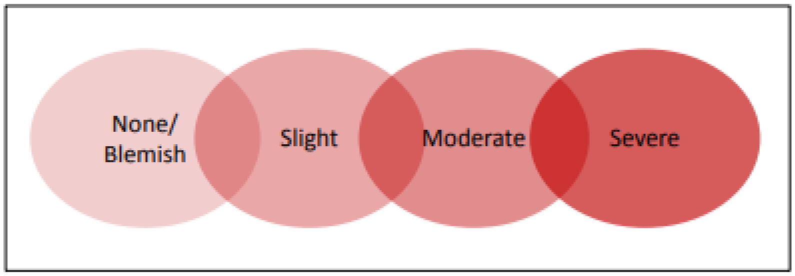


Figure 1 - Segregation Severity Continuum

Reference photographs of various severities of pavement segregation and Obvious Defect sites are located in Appendix A.

3.0 SEGREGATION INSPECTION AND REPORTING

Inspections of the top lift pavement are to be completed by the Consultant on an on-going basis during construction and provided to the Contractor in a timely manner. All areas of segregation, Centre-of-Paver streaks and Obvious Defects should be marked on the pavement. The Consultant should review the marking scheme used with the Contractor to avoid misunderstandings in the segregation assessments or repair requirements. Areas identified are to be recorded on the Segregation Inspection Worksheet.

The Consultant uses the information recorded on the Segregation Inspection Worksheet to calculate payment adjustments and summarizes that on the Segregation Summary Report. The Segregation Summary Report is to be included within the Final Details package (submitted along with the other required documents to trans.constructqa@gov.ab.ca). The Segregation Inspection Worksheet (B.17) and Segregation Summary Report (B.18) are in Appendix B of the Engineering Consultant Guidelines for Highway, Bridge and Water Projects – Vol. 2 (available at http://www.transportation.alberta.ca/919.htm). Both documents are provided in Excel format to assist in calculating the payment adjustments. Completed examples are also included within these documents.

3.1. Segregation Payment Adjustment Calculations

Segregated sites on entrances and approaches should be identified for repair but do not affect the segregation payment adjustments. Likewise, sites with Obvious Defects are identified for repair only. Individual sites of segregation which are separated by less than 3 m are considered to be a single site for the determination of payment adjustments. Similarly, in the Segregation Inspection Worksheet, the Centre-of-Paver streaks should only be marked in that column, without a checkmark in the severity column to avoid double counting the site. Data should not by copy/pasted to the spreadsheets to avoid altering the imbedded formulas.

Prorating for payment adjustments is done automatically within the excel Segregation Summary Report. Below is an explanation of the calculations done to determine the prorated payment adjustment for Slight Segregation, **these are accounted for automatically in the excel Segregation Summary Report**.

For example:

0.560 km with 2 slight areas of segregation and no other areas of segregation. Since slight segregation frequency has an allowance of 2 sites per kilometre, there is a requirement to prorate the frequency and payment adjustment for a partial lane.km.

Segregation Frequency (Slight) = 2 sites/0.560 km = 3.57 = 4 sites (rounded to whole number)

Payment Adjustment = -(4-2) × \$100 = -\$200

Prorated Payment Adjustment = -\$200 × 0.560 = -\$112

4.0 SEGREGATION REPAIRS

Table 1 further summarizes segregation repair requirements outlined in Edition 15 of the Standard Specifications.

Table 1 - Segregation Repair Requirements

Segregation Type	Lower Lift(s)	Top Lift
Slight Segregation	Contractor option to repair	Contractor option to repair
Moderate Segregation	Contractor option to repair	Repair
Severe Segregation	Repair if segregated area will affect the long term structural integrity of the pavement structure	Repair (including entrances and intersections)
Center of Paver Streak	Contractor option to repair	Repair (only if Moderate/ Severe)
Obvious Defects	Repair not typically required	Repair

The following methods of repair are pre-approved according to the Specifications:

- Moderate Segregation: Slurry Patch or Hot Mix Patch
- Severe Segregation: Remove and replace or overlay

The following factors should be considered for approval of a slurry patch product (there is no category for segregation repair products in Alberta Transportation's Approved Products List):

- The product must be a slurry (a uniform mixture of asphalt emulsion, fine aggregate and other additives).
- The product should be intended for use on asphalt surfaces.
- The product should not deteriorate the pavement ride.
- The product should be able to provide a neat application.
- Application of blotter sand or cement on top of the slurry to reduce tracking is acceptable.
- Commercial or proprietary products are acceptable if they meet all other requirements.
- Hand laid slurry patches are acceptable if they provide a good finished product.

The following methods are generally **not** acceptable: restorative or rejuvenating sand seal treatment, spray patching, application of asphalt by distributor, hand spraying, squeegeeing asphalt by itself (current specifications explicitly disallow this method), or application of asphalt followed by sprinkling of sand.

5.0 APPEAL PROCEDURES

As outlined in the specifications the Contractor may appeal the segregation ratings and payment assessments. In such cases the Project Sponsor is to forward the following information to the Pavement Engineering Section, Attn: Roadway Construction Standards Specialist:

- Contractor’s written Notice of Appeal
- Prime Consultant’s original assessment (including worksheets)
- Confirmation that the sites in the appeal have not been repaired

TSB staff will coordinate with the Consultant and Region to undertake an inspection of the appealed portion of work. The Contractor is to be informed of the inspection schedule and can be present during the inspection but is not to be involved in the actual reassessment.

The Region typically arranges for traffic control through the local MCI and maintenance contractor. In some cases the paving contractor may be able to provide this service. The appeal team will typically inspect 4 lane·km of pavement to determine whether the original assessment and payment adjustments are valid or if the inspection work needs to be redone.

Responsibility for the payment of costs associated with the appeal testing (Contractor versus Department) is described in section 3.50.4.9.6 of Specification 3.50 ACP – EPS.

Appendix A

List of Photographs

Photograph 1- Slight Segregation

Photograph 2 - Slight Segregation

Photograph 3 - Slight Segregation

Photograph 4 - Slight Segregation (Close up)

Photograph 5 - Moderate Segregation

Photograph 6 - Moderate Segregation

Photograph 7 - Moderate Segregation

Photograph 8 – Moderate (bordering on Severe) Segregation

Photograph 9 - Moderate Segregation (bordering on Severe) (Close-Up)

Photograph 10 - Severe Segregation

Photograph 11 - Severe Segregation

Photograph 12 - Severe Segregation (Close-Up)

Photograph 13 - Centre-of-Paver Streak

Photograph 14 - Improperly Matching Joint (View 1)

Photograph 15 - Improperly Matching Joint (View 2)

Photograph 16 - Obvious Defect (Improperly Repaired Core Holes)

Photograph 17 - Obvious Defect (Hairline Cracking)

INFRASTRUCTURE AND TRANSPORTATION

GUIDELINES FOR ASSESSING PAVEMENT PRESERVATION TREATMENTS AND STRATEGIES

EDITION 2 **JULY, 2006**

Pages 29, 36-39

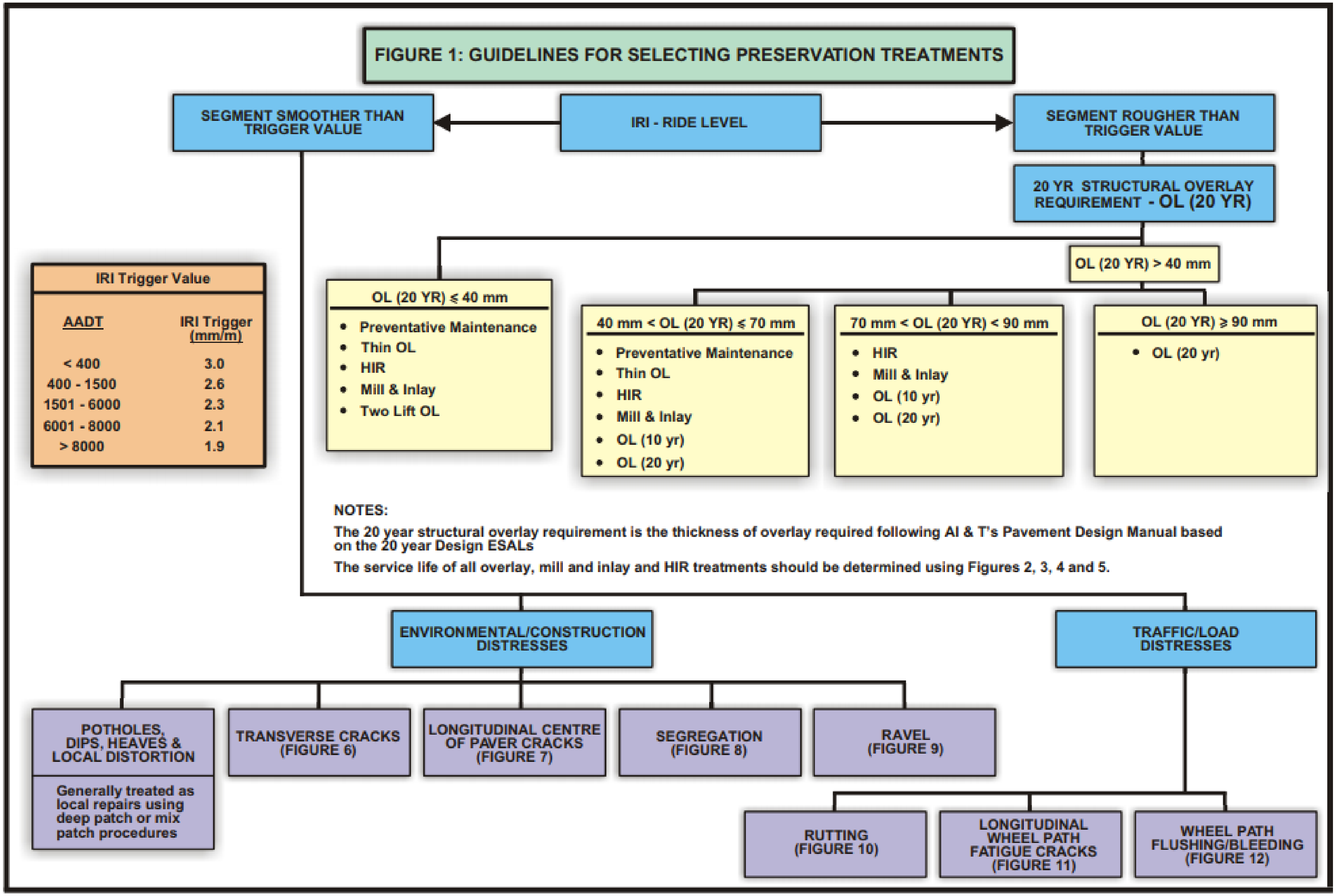
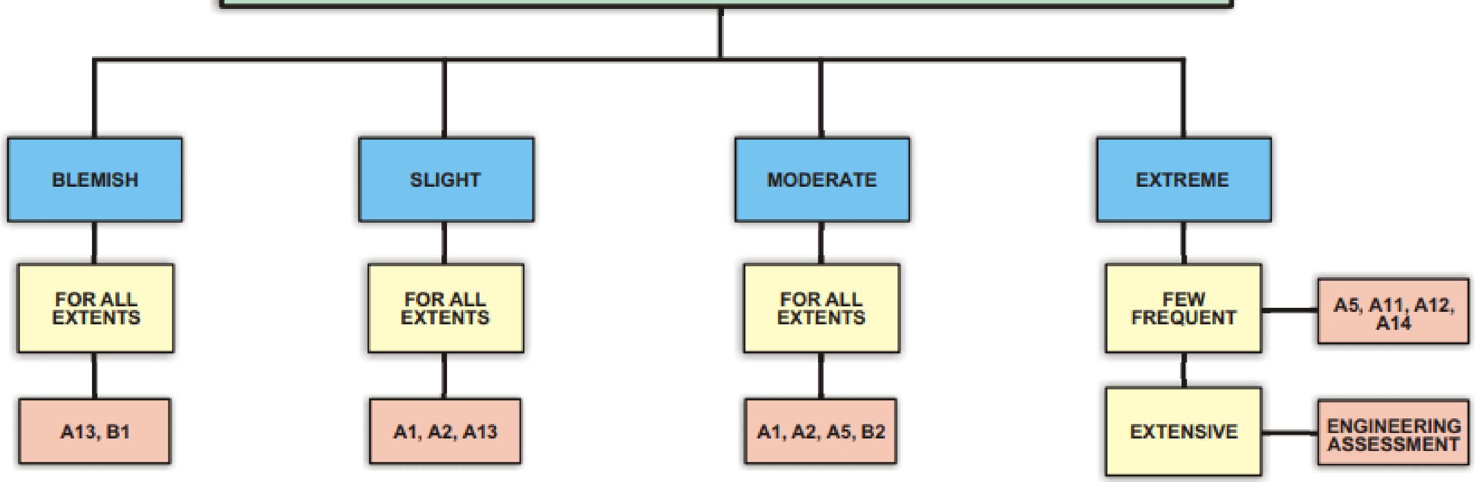


FIGURE 1: GUIDELINES FOR SELECTING PRESERVATION TREATMENTS
SEGMENT SMOOTHER THAN TRIGGER VALUE
IRI - RIDE LEVEL
SEGMENT ROUGHER THAN TRIGGER VALUE
20 YR STRUCTURAL OVERLAY REQUIREMENT - OL (20 YR)
OL (20 YR) > 40 mm
IRI Trigger Value
AADT
IRI Trigger (mm/m)
< 400 3.0
400 - 1500 2.6
1501 - 6000 2.3
6001 - 8000 2.1
> 8000 1.9
OL (20 YR) ≤ 40 mm
Preventative Maintenance
Thin OL
HIR
Mill & Inlay
Two Lift OL
40 mm < OL (20 YR) ≤ 70 mm
Preventative Maintenance
Thin OL
HIR
Mill & Inlay
OL (10 yr)
OL (20 yr)
70 mm < OL (20 YR) < 90 mm
HIR
Mill & Inlay
OL (10 yr)
OL (20 yr)
OL (20 YR) ≥ 90 mm
OL (20 yr)
NOTES:
The 20 year structural overlay requirement is the thickness of overlay required following AI & T's Pavement Design Manual based on the 20 year Design ESALs
The service life of all overlay, mill and inlay and HIR treatments should be determined using Figures 2, 3, 4 and 5.
ENVIRONMENTAL/CONSTRUCTION DISTRESSES
TRAFFIC/LOAD DISTRESSES
POTHOLES, DIPS, HEAVES & LOCAL DISTORTION
Generally treated as local repairs using deep patch or mix patch procedures
TRANSVERSE CRACKS (FIGURE 6)
LONGITUDINAL CENTRE OF PAVER CRACKS (FIGURE 7)
SEGREGATION (FIGURE 8)
RAVEL (FIGURE 9)
RUTTING (FIGURE 10)
LONGITUDINAL WHEEL PATH FATIGUE CRACKS (FIGURE 11)
WHEEL PATH FLUSHING/BLEEDING (FIGURE 12)

FIGURE 7: TREATMENT MATRIX FOR LONGITUDINAL CENTRE-OF-PAVER CRACKS



SEVERITY DEFINITION
(Reference Pages 31, 32, 48 & 49 of AIT SCRM V4.2)

Blemish: Appears as a continuous or semi-continuous straight longitudinal "streak" typically located in the middle of the paver "mat".

Repaired: Repaired with A1, A2 or A3 where no opening is evident; bonds are intact.

Slight: Single cracks ≤ 3 mm, cracks repaired with A1, A2 orA3 but sealant not bonded.

Moderate: All single cracks cracks > 3 mm and < 10 mm, branched cracking with branching interval of 3 or more branches per lin. m., Secondary cracks are present.

Extreme: All cracks ≥ 10 mm wide, multiple cracking, spalling with considerable break-up and loss of material.

EXTENT DEFINITION - Percent of the Length Affected in Each Lane

Few - < 20%
Frequent - 20 to 50%
Extensive - > 50%

Preventative Maintenance Treatments		Surface Treatments		Rehabilitation Treatments	
A1	Crack Fill	B1	Fog Coat	C1	HIR
A2	B&G Crack Fill	B2	Spot Seal Coat	C2	M&I
A3	R&S Crack Seal	B3	Seal Coat	C3	Thin OL
A4	Re-seal R&S	B4	Slurry Seal	C4	Reprofiling and OL
A5	SP (Cracks)	B5	Micro-Surfacing	C5	M&I or HIR and OL
A6	SP (spot)	B6	Reprofiling	C6	Deep M&I
A7	Thermo-Patch			C7	Whitetopping
A8	Micro-Surfacing Patch			C8	Thick OL
A9	Diamond Grind (Cracks)			C9	Structural OL
A10	Shallow Mill and SP (Cracks)				
A11	Shallow M&F (Cracks)				
A12	Deep M&F (Cracks)				
A13	Squeegee Patch				
A14	Mix Patch				
A15	Deep Patch				

INTERPRETIVE NOTES

1) Longitudinal Centre-of-Paver cracks not located in wheel paths with slight severity can be considered for an A3 treatment option.

2) Longitudinal Centre-of-Paver cracks are readily distinguishable from longitudinal fatigue cracks. The former are generally very straight; the latter tend to meander within the wheel path.

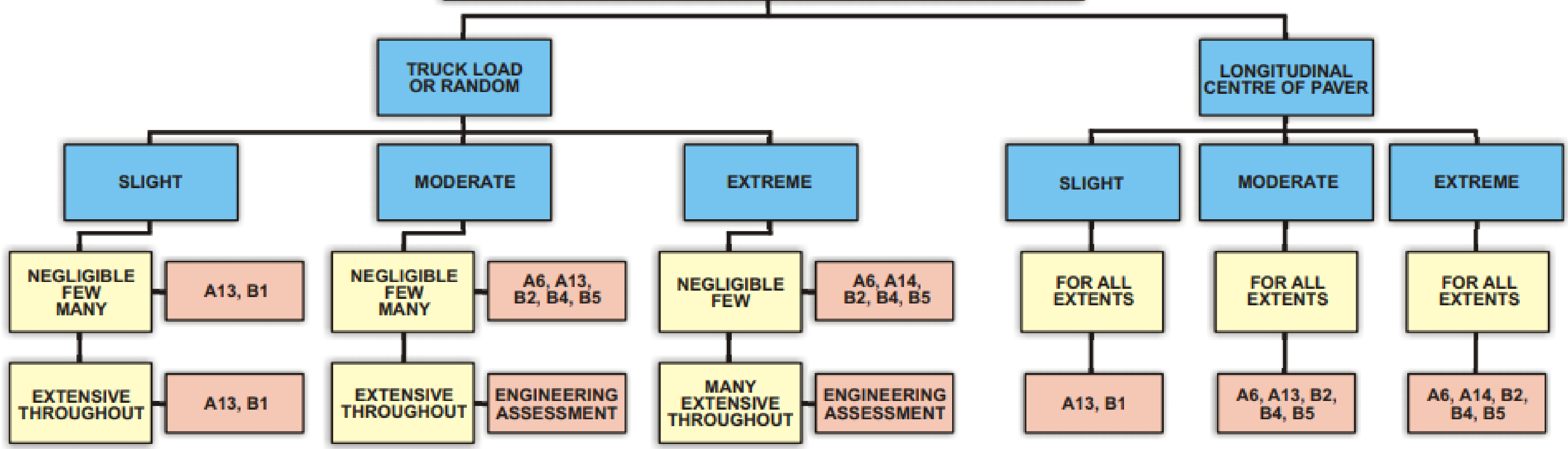
3) The Blemish Severity is generally an indication of segregation in the asphalt mix (refer to Figure 8 for more detailed information).

4) Longitudinal Centre-of-Paver cracks located in the wheel paths can deteriorate and have short transverse fatigue cracks and fatigue blocking associated with them. In this situation the assessment should use Figure 11 - Fatigue Cracking.

Moderate Severity Centre-of-Paver Crack

Centre-of-Paver Crack Located in Outer Wheel path

FIGURE 8: TREATMENT MATRIX FOR SEGREGATION



SEVERITY DEFINITION
(Reference Spec 3.50.4.7.2)

Slight: The matrix, asphalt cement and fine aggregate is in place between the coarse aggregate. However, there is more stone in comparison to the surrounding area.

Moderate: Significantly more stone than the surrounding mix. Moderately segregated areas usually exhibit a lack of surrounding asphalt and fine aggregate matrix.

Extreme: Appears as an area of very stony asphalt mix, stone against stone with very little or no fine aggregate matrix.

EXTENT DEFINITION

TRUCK LOAD OR RANDOM
(number/lane-km)
(Reference AIT SEAL COAT RATING GUIDELINES)

Negligible - < 5
Few - 5 to 10
Many - 11 to 20
Extensive - 21 to 30
Throughout - > 30

LONGITUDINAL CENTRE OF PAVER
(Percent of Length of Lane Affected)

Few - < 10%
Intermittent - 10 to 20%
Frequent - 20 to 50%
Extensive - 50 to 80%
Throughout - 80 to 100%

Preventative Maintenance Treatments		Surface Treatments		Rehabilitation Treatments	
A1	Crack Fill	B1	Fog Coat	C1	HIR
A2	B&G Crack Fill	B2	Spot Seal Coat	C2	M&I
A3	R&S Crack Seal	B3	Seal Coat	C3	Thin OL
A4	Re-seal R&S	B4	Slurry Seal	C4	Reprofiling and OL
A5	SP (Cracks)	B5	Micro-Surfacing	C5	M&I or HIR and OL
A6	SP (spot)	B6	Reprofiling	C6	Deep M&I
A7	Thermo-Patch			C7	Whitetopping
A8	Micro-Surfacing Patch			C8	Thick OL
A9	Diamond Grind (Cracks)			C9	Structural OL
A10	Shallow Mill and SP (Cracks)				
A11	Shallow M&F (Cracks)				
A12	Deep M&F (Cracks)				
A13	Squeegee Patch				
A14	Mix Patch				
A15	Deep Patch				

INTERPRETIVE NOTES

1) Moderate and extreme severity segregated areas will ravel quickly. Immediate identification and treatment of these areas will reduce the rate of deterioration significantly.

2) Treatment A13 - Squeegee Patch, is generally hand placed using a variety of materials. For slight severity, a application of an emulsified asphalt similar to a fog seal would be appropriate. Moderate and Extreme severity areas could have emulsified asphalt with fine sand mixed in or use of proprietary products for spot patching.

3) Longitudinal Centre of Paver segregation will appear as a straight longitudinal continuous or semi-continuous streak, typically located in the middle of the paved mat.

4) Segregated areas that have experienced ravel should be assessed for treatment using the RAVEL treatment decision tree (Figure 9).

5) When treating Segregated areas, treatments should extend beyond the visible edge of the segregated area.

6) Segregated areas that are left untreated are subject to ravel and premature fatigue cracking.

7) Segregated areas that have been treated as part of the pavement construction process should be monitored for additional treatment on a continuing basis.

8) When an Engineering Assessment is required, the AI & T Guidelines for the Assessment, Rating and Prioritization of Pavements for Seal Coat should be used as the primary procedure.

Segregation

Segregation

Segregation

ALBERTA TRANSPORTATION GUIDELINES FOR THE ASSESSMENT, RATING AND PRIORIZATION OF PAVEMENTS FOR SEAL COAT

TRANSPORTATION

September, 2000

ALBERTA TRANSPORTATION GUIDELINES FOR THE ASSESSMENT, RATING AND PRIORIZATION OF PAVEMENTS FOR SEAL COAT

INTRODUCTION

The purpose of this document is to present relevant background information and to provide guidelines for using the seal coat rating system. This system is normally used to establish needs for chip seal coats on Primary Highways.

Alberta Transportation primarily uses seal coats to repair surface deficiencies, to protect the surface and prevent water ingression. Pavements that are good candidates for a seal coat exhibit surface characteristics that could to lead to ravelling, stripping, potholes and structural failures if left unprotected. Projects that are considered as high priority have pavement surfaces already showing signs of these problems occurring to some degree.

In order for Alberta Transportation to develop, an annual seal coat program within the framework of a limited budget, a system has been developed to establish priorities, objectively on a Regional and Province wide basis.

BACKGROUND

Seal coats have been applied to paved roadways in Alberta since 1941. Commencing in 1959, a planned seal coat program was developed each year as the final phase of pavement construction, and until the mid 1980's pavements were routinely seal coated within a few years of being paved. In the 1980's the Departments budgetary capacity for seal coat construction was approximately 1500 lane kilometres annually and since the early 1990's, this capacity has significantly reduced. No longer are funds available to seal coat all pavements and thus, it is very important to select only those that are in real need, to extend the life of the pavement.

Prior to the 1990's the preparation of the seal coat program consisted of assessing the needs and priorities based on structural adequacy of the pavement, surface condition, age of pavement and traffic volume. An expert within the Department was relied upon to use his best judgement to rank the various candidate projects for programming purposes. A more scientific approach was developed in the early 1990's using a computerized Expert System known as SECOA (Seal Coat Adviser).

This system incorporated the Department expert’s judgement as to which attributes of the pavement should be input as well as the relative importance of each with regard to rating and ranking projects, based on the need for seal coat. The weighting factors applied to each attribute were adjusted until there was close agreement between the system’s priority list and the independently developed list of the Department expert. The SECOA system included 11 attributes which were judged for each candidate project. Two of the attributes were traffic volume and pavement age, the other 9 related to pavement condition. Site inspections were carried out to assess the various pavement condition attributes and severity levels for each and a rating form with all relevant information completed and submitted for processing. With all required information input, the Expert System calculated a total score for each candidate project which enabled a priority list to be prepared with the projects having the highest total score ranking highest on the priority list.

In 1995 the seal coat rating system was re-evaluated and several modifications and improvements were made.

CURRENT RATING SYSTEM

The latest system in place for rating potential seal coat projects is a relatively simple one, that does not require computer processing. It is based on the original SECOA system concept, incorporating the changes made in 1995. This new system involves the assessment of 7 attributes, 5 of which relate to pavement condition.

GUIDELINES FOR SEAL COAT RATING AND PRIORIZATION

Regional offices of Alberta Transportation and Utilities will provide a list of pavement projects to be considered as candidates for the seal coat program. Each of these projects are to be inspected, rated and evaluated to determine a total score and ranking on the priority list.

The following attachments are to be used:
1) Explanatory Notes
2) Rating Sheet (Sheet 'A')
3) Weighting Factors (Table 1)
4) Scoring Sheet (Sheet 'B')
Each project should be inspected objectively and critically, in accordance with the explanatory notes and the rating sheet form completed accordingly. The explanatory notes are intended to provide a basis upon which each attribute may be quantified in order to translate visual perceptions into objective numbers. To assist the Rater in judging those attributes on the basis of a 0.1m² area of pavement, it may prove useful to utilize a cardboard cut-out or template of some sort with a 33 cm by 33 cm opening providing a one-tenth square metre area.

All judgements made should be representative of the proposed project as a whole, rather than of short sections of it.

Inspections and ratings should be carried out if possible during the months of July and August when daylight conditions are most favourable. Autumn inspections, when the sun is closer to the horizon, are more difficult to perform because of the shadows created which could give the rater a false impression about some of the attributes.

The inspection should involve a drive through, in both directions as well as walking a few short sections to view the paved surface close up to rate the individual attributes.

If possible two experienced individuals should rate projects particularly those that are likely to be in the higher priority category. The inspection could be done jointly or separately and where there is a difference agreement should be reached as to the most appropriate severity level rating.

The rating sheet, including project information and any relevant remarks should be completed, as shown on the attached example. Use one sheet for each project, describing it by the appropriate from and to limits, control section number and kilometres. As far as possible, individual paving jobs should be used as candidate project limits. Where combinations of adjacent paving jobs are being considered, each should be rated separately.

When the projects on the list have been inspected and rating sheets completed for each, weighting factors are to be determined for each attribute and a total score calculated. Using the weighting factors provided, the seal coat scoring sheet is to be filled out, as shown on the attached example. The total score, thus determined, is used to rank the projects on a priority basis. The higher the score, the greater need for seal coat.

The priority list, arranged in order of highest priority to lowest should be prepared, to assist in developing the seal coat program on a regional and provincial basis. The list should include the rank, project description, total score, lane kilometres, estimated cost and remarks.

The final submission should include a rating sheet and scoring sheet for each project as well as an overall priority list.

Highway Engineering, TSB
September, 2000

EXPLANATORY NOTES

ON THE

ASSESSMENT OF

PAVEMENT SURFACES

FOR

SEAL-COAT APPLICATION

1. SEGREGATED AREAS AND RAVELLING

SEGREGATED AREAS

Segregated areas are seen as changes in the consistency of pavement surface texture. Segregation occurs when the pavement is laid down, but need not become evident until much later. It often occurs at regular intervals along a pavement and in the same transverse position, corresponding to individual truckloads of mix, but it can also be seen as a narrow band continuously along a surface, often associated with the center of a paver mat or with the joint between two mats. Individual segregated areas are often typically about 0.5 by 1 m in size.

A) RAVELLING IN SEGREGATED AREAS

Asphalt matrix and fine aggregate was either not there in the first place or has disappeared. The aggregate particles are now being dislodged and are disappearing, along with the asphalt binder.

Measures of Ravelling in Segregated Areas:
For the purposes of rating, consider the worst 0.1m^2 (one square foot) are of ravelling within the segregation.

None: There is no evidence of ravelling yet in such segregated areas as can be observed.
Slight: It is evident that ravelling has begun but less than 25% of the aggregate and binder has been lost from the top surface of the pavement.
Moderate: 25% to 50% of the aggregate and binder has ravelled away from the top surface of the pavement.
Severe: Over 50% of the aggregate and binder has disappeared from the top surface of the pavement.

Note: If the depth of the segregation is greater than 10 to 15 mm (a depth about equal to the aggregate top size), a patch may be required before a seal coat is applied.

B) FREQUENCY OF SEGREGATED AREAS

Counting the number of segregated areas per lane-kilometer of road provides a measure of the extent of the ravelling problem.

Measures of the average number of segregated areas per lane-kilometer:

- **Negligible:** There are less than 5 segregated areas per lane-km.
- **Few:** There are 5 to 10 segregated areas per lane-km.
- **Many:** There are 11 to 20 segregated areas per lane-km.
- **Very Many:** There are more than 20 segregated areas per lane-km, or the segregation is continuous as a narrow band.

SEAL COAT RATING SHEET "A"

(Judgement of the Attributes of Pavements as Candidates for Seal Coat Application)

PROJECT NUMBER ______________________ PAVING CONTRACT NUMBER: __________

PROJECT DESCRIPTION

From: ____

To: ____

Control Section: __________ From Km. __________ To Km. __________

Control Section: __________ From Km. __________ To Km. __________

Control Section: __________ From Km. __________ To Km. __________

RATING CATEGORY N.B.: Circle the appropriate "Rating" for each attribute observed.

1. Segregated Areas	a) Ravelling	None	Slight	Moderate	Severe
	b) Frequency	Negligible	Few	Many	Very Many
2. Aggregate Loss (Exclusive of Segregation)	a) General Ravelling	Negligible	Slight	Moderate	Severe
	b) Coarse Roak Loss	Negligible	Slight	Moderate	Severe
3. Hairline Cracking	a) Severity	None	Slight	Moderate	Severe
	b) Extent	Negligible	Slight	Moderate	Severe
4. Presence of Foreign Material		Negligible	Slight	Moderate	Severe
5. Pavement Surface Texture		High	Normal	Low	Very Low
6. Traffic Volume (AADT =	________________)	Low	Moderate	High	Very High
7. Age of Pavement Surface	(__________ Years)	1 to 3	4 to 6	7 to 9	>9

N.B.: Pavements with excessive bleeding, rutting or longitudinal / alligator cracking should not be considered as candidates for Seal Coat application.

Remarks: ____

Inspected By: ______________ Consultant: __________8__________ Date: ______________ Region: ______________

SEAL COAT RATING – SHEET "B"

PROJECT NUMBER: ________________ **PAVING CONTRACT NUMBER:** ________________

PROJECT DESCRIPTION

From: ____

To: ____

Control Section: ________ **To Km:** ________ **To Km:** ________

Control Section: ________ **To Km:** ________ **To Km:** ________

Control Section: ________ **To Km:** ________ **To Km:** ________

RATING CATEGORY		Rating (Sheet A)	Weigthing Factor (Table 1)	Score	
1. Segreated Areas	A) Ravelling			A x B	
Segreated Areas	B) Frequency				
2. Aggregate Loss (Exclusive of Segregation)	A) General Ravelling			A + B	
	B) Coarse Rock Loss				
3. Hairline Cracking	A) Severity			A x B	
Hairline Cracking	B) Extent				
4. Presence of Foreign Material	A) Severity				
5. Pavement Surface Texture					
6. Traffic Volume	AADT =				
7. Age of Pavement Surface	Years				
				Total Score	

9

nspected By: ____________ **Consultant:** ____________ **Date:** ____________ **Region:** ____________

SEAL COAT WEIGHTING FACTORS

Table 1

RATING CATEGORY		WEIGHTING FACTORS							
1. Segregated Areas	A) Ravelling	None	2.0	Slight	5.0	Moderate	13.0	Severe	18.0
	B) Frequency	Negligible	0.0	Few	1.0	Many	2.0	Very Many	3.0
2. Aggregate Loss (Exclusive of Segregation)	A) General Ravelling	Negligible	0.0	Slight	5.0	Moderate	17.0	Severe	40.0
	B) Coarse Rock Loss	Negligible	0.0	Slight	1.0	Moderate	5.0	Severe	12.0
3. Hairline Cracking	A) Severity	None	0.0	Slight	2.0	Moderate	5.0	Severe	7.0
	B) Extent	Negligible	0.0	Slight	1.0	Moderate	2.0	Severe	3.0
4. Presence of Foreign Material		Negligible	0.0	Slight	1.0	Moderate	2.0	Severe	5.0
5. Pavement Surface Texture		High	0.0	Normal	0.0	Low	6.0	Very Low	10.0
6. Traffic Volume (AADT=_______)		AADT/1000 (Maximum 15)							
7. Age of Pavement Surface (_____years)		Age-3 (Maximum 7)							

Arizona

406-6 Construction Requirements:
The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.
Same text also appears under: 407-7.04 Placing and Finishing: (A) General Requirements:
Same text also appears under: 413-7.04 Placing and Finishing: (A) General Requirements:
Same text also appears under: 414-7.04 Placing and Finishing: (A) General Requirements:
Same text also appears under: 415-6 Construction Requirements:
Same text also appears under: 416-6 Construction Requirements:
Same text also appears under: 417-6 Construction Requirements:

(C) Placing and Finishing Asphaltic Concrete by Means of Self-Propelled Paving Machines:
All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.
In order to achieve, as far as practical, a continuous operation, the speed of the paving machine shall be coordinated with the production of the plant.
Self-propelled paving machines shall spread the mixture without segregation or tearing within the specified tolerances, true to the line, grade, and crown indicated on the project plans. Pavers shall be equipped with hoppers and augers which will distribute the mixture uniformly in front of adjustable screeds.

Q21 response to survey: https://azdot.gov/sites/default/files/media/2019/11/2008-standards-specifications-for-road-and-bridge-construction.pdf 417-6 Construction Requirements Pg. 416

417-6 Construction Requirements:

The contractor shall be responsible for the proportioning of all materials, for the hauling, placing, loading, spreading and finishing of asphaltic concrete, and for the applying of bituminous material, such as tack coats, prime coats and provisional seals, all in accordance with the appropriate portions of the specifications.

The asphaltic concrete hot plant shall conform to the requirements of Section 403 of the Specifications.

The temperature of asphaltic concrete or mineral aggregate upon discharge from the drier shall not exceed 325 ºF unless a higher temperature is recommended in writing by the asphalt binder supplier and approved by the Engineer.

All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.

Pavers shall be equipped with a screed for the full width being paved, heated if necessary, and capable of spreading and finishing all courses of asphaltic concrete.

Pavers shall be equipped with automatic screed controls with sensors for either or both sides of the paver, capable of sensing grade from an outside reference line, sensing the transverse slope of the screed, and providing the automatic signals which operate the screed to maintain the desired grade and transverse slope.

Failure of the control system to function properly shall be cause for the suspension of the placing of asphaltic concrete.

The base or subgrade upon which asphaltic concrete is to be placed shall be prepared and maintained in a firm condition until asphaltic concrete is placed. It shall not be frozen or excessively wet.

At any time the Engineer may require the work to cease or that the work day be reduced in the event of weather conditions, either existing or expected, which would have an adverse effect upon the asphaltic concrete.

All wheels and tires of compactors and other equipment surfaces shall be treated when necessary with a product approved by the Engineer in order to prevent the sticking of asphaltic concrete.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of objectionable material.

Longitudinal joints of each course shall be staggered a minimum of one foot with relation to the longitudinal joint of any immediate underlying course.

When surfacing courses are placed on ten foot or wider shoulders which are to receive rumble strips, the contractor shall place any longitudinal joints approximately one foot away from the travel lane side of the rumble strip.

Longitudinal joints shall be located within one foot of the center of a lane or within one foot of the centerline between two adjacent lanes. Joints shall be formed by a slope shoe or hot-lapped, and shall result in an even, uniform surface.

Before a surface course is placed in contact with a cold transverse construction joint, the cold existing asphaltic concrete shall be trimmed to a vertical face by cutting the existing asphaltic concrete back for its full depth of the lift and exposing a fresh face. After placement and finishing of the new asphaltic concrete, both sides of the joint shall be dense and the joint shall be well sealed. The surface in the area of the joint shall conform to the requirements hereinafter specified for surface tolerances when tested with the straightedge placed across the joint.

All locations where plate samples are taken from the roadway shall be immediately repaired by the contractor utilizing hot asphaltic concrete. All holes where cores are taken shall be repaired within 48 hours after coring using a material approved by the Engineer. All holes shall be in a dry condition prior to repair. The patching material shall be thoroughly compacted in the holes by the contractor.

The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.

A light coat of bituminous material shall be applied as directed to edges or vertical surfaces against which asphaltic concrete is to be placed.

The contractor shall schedule its paving operations to minimize exposed longitudinal edges. Unless otherwise approved by the Engineer, the contractor shall limit the placement of asphaltic concrete courses, in advance of adjacent courses, to one shift of asphaltic concrete production. The contractor shall schedule its paving operations in such a manner to eliminate exposed longitudinal edges over weekends or holidays.

The moisture content of the asphaltic concrete immediately behind the paver shall not exceed 0.5 percent. The moisture content will be determined in accordance with Arizona Test Method 406.

Arkansas

404.04 Quality Control of Asphalt Mixtures. The Contractor shall perform all applicable quality control sampling and testing of the asphalt mixtures used on the project.

Property	**Test Method(s)** (NOTE 1)
Aggregate Gradation	AASHTO T 30, AHTD 460, or AASHTO T 308 1 per 750 metric tons (750 tons) minimum
Asphalt Binder Content (NOTE 4)	AHTD 449/449A or AASHTO T 308
Stability	AASHTO T 245
Air Voids (AV) (NOTE 2)	AASHTO T 269
Voids in Mineral Aggregate (VMA)	AHTD 464
Density - Maximum Theoretical	AASHTO T 209
Density (Field)	AASHTO T 166 or AHTD 461
Water Sensitivity (NOTE 3)	AHTD 455A
Wheel Tracking Test	AHTD 480

NOTE 1: Where alternate test methods are shown, the method used shall be at the Contractor's option. All testing for quality control and acceptance shall be performed on samples of the plant mixed product. Field densities and samples to investigate segregation shall be taken from the roadway after compaction; all other samples shall be taken from trucks at the plant.

409.04 Equipment. (a) Mechanical Spreading and Finishing Equipment.
The term "screed" shall include any strike-off device, operated by cutting, crowding, or other practical action that effectively places and spreads the mixture without tearing, shoving, gouging, or segregating. Screeds shall be adjustable to crown and grade and shall have an indicating level attached.

The MTD/MTV, haul units, and paver shall work together to provide a continuous, uniform, segregation free flow of material. The number of haul units, speed of the paver, plant production rate, and speed of the MTD/MTV shall be coordinated to avoid stop and go operations. The wings of the paver receiving hopper shall not be raised (dumped) at any time during the paving operation

410.09 Acceptance of the Pavement and Adjustments in Payment. (a) General.
(b) Acceptance of the Pavement. Acceptance of ACHM courses will be based on the following criteria:

• The results of tests for the properties listed in Table 410-1,

• Pavement smoothness, and
• Segregation.

(3) Segregation. Segregation in asphalt concrete hot mix paving is the non-uniform distribution of aggregate that results in non-uniform surface texture. If a pattern of segregation develops, or if segregation occurs over a large area (3 square yards [3 sq m] or more), paving shall cease until the problem has been corrected.
Visual inspection of the compacted pavement will be made to determine the extent of any segregation. In addition to the visual inspection, objectionable areas may be tested. Samples will be obtained from the areas identified as objectionable by the Engineer. Gradation, density, and asphalt binder content of the samples will be determined according to the test methods in Section 404.04. The test values obtained shall be within the tolerances for gradation in Section 404.04 and within the compliance limits for asphalt binder content and density in Section 410. If any of the test results do not meet the requirements, the area/areas will be considered non-complying. If the non-complying material is deemed reasonably acceptable according to Subsection 105.04, it may be left in place at a reduced cost to the Department.
In the event the material is found unacceptable relative to segregation and it is determined that the material must be removed, the area(s) of segregation shall be removed full depth of the course paved. Replacement of the material by dumping and spreading by hand or motor grader will be permitted on base and binder courses for areas less than 50 linear feet (15 m) in length. Replacement of larger areas of base and binder and replacement of any surface course will be accomplished with a paver. On surface course, the minimum area to be removed shall be 50 linear feet (15 m) of the full width of the mat paved.

410.10 Incentives.
(a) An incentive payment of 3.0% will be added if:
• the asphalt binder content is within ±0.2 percentage point of the mix design value, and
• the total variation, low to high, in air voids is no more than 0.6%, with none outside of the compliance limits, and
• all densities fall between 92.0%* and 96.0%, and
• there are no areas of segregation outside of the compliance limits as verified by testing according to Subsection 410.09(b)(3)
*When the minimum specification density is 90.0%, this value is changed to 90.0%.

California

https://dot.ca.gov/-/media/dot-media/programs/design/documents/f00203402018stdspecs-a11y.pdf

California specifications do not cover AC segregation to any great extent. What is noteworthy is the many uses of the word "segregation", with examples below:

SECTION 5 CONTROL OF WORK
5-1.43D Full and Final Potential Claim Record
Within 30 days of the completion of the potentially claimed work, submit a Full and Final Potential Claim Record form including:
3. Itemized cost breakdown if a payment adjustment is requested. Segregate costs into the following categories:
. . .

SECTION 7 LEGAL RELATIONS AND RESPONSIBILITY TO THE PUBLIC
7-1.11B FHWA-1273

Ill. NONSEGREGATED FACILITIES
This provision is applicable to all Federal-aid construction contracts and to all related construction subcontracts of $10,000 or more.
The contractor must ensure that facilities provided for employees are provided in such a manner that segregation on the basis of race, color, religion, sex, or national origin cannot result. The contractor may neither require such segregated use by written or oral policies nor tolerate such use by employee custom. The contractor's obligation extends further to ensure that its employees are not assigned to perform their services at any location, under the contractor's control, where the facilities are segregated. The term "facilities" includes waiting rooms, work areas, restaurants and other eating areas, time clocks, restrooms, washrooms, locker rooms. and other storage or dressing areas, parking lots. drinking fountains. recreation or entertainment areas, transportation, and housing provided for employees. The contractor shall provide separate or single-user restrooms and necessary dressing or sleeping areas to assure privacy between sexes.

SECTION 14 ENVIRONMENTAL STEWARDSHIP
14-11.14 TREATED WOOD WASTE
14-11.14C Training
Provide training to personnel who handle or may come in contact with treated wood waste. Training must include:
1. Requirements of 8 CA Code of Regs
2. Procedures for identifying and segregating treated wood waste
. . .
14-11.14D Storage of Treated Wood Waste
Resize and segregate treated wood waste at a location where debris including sawdust and chips can be contained. Collect and manage the debris as treated wood waste.

SECTION 19 EARTHWORK

19-3.03F Slurry Cement Backfill
Place slurry cement backfill within 1 hour of mixing. Place it in a uniform manner that prevents (1) voids or segregation of the backfill and (2) floating or shifting of the culverts. Remove foreign material that falls into trenches.

SECTION 25 AGGREGATE SUBBASES
25-1.03D Spreading
Deliver uniform mixtures of AS to the roadbed. Deposit AS in layers or windrows. Spread and shape the AS to such thickness that after watering and compacting, the completed AS is within the tolerances specified in section 25-1.03E. When AS is spread and compacted the moisture content must be uniform and sufficient to obtain the required compaction. Avoid material segregation. AS must be free from pockets of coarse or fine material.

SECTION 26 AGGREGATE BASES
26-1.03D Spreading
Deliver uniform mixtures of AB to the roadbed. Deposit AB in layers or windrows. Spread and shape the AB to such thickness that after watering and compacting, the completed AB is within the tolerances specified in section 26-1.03E. When AB is spread and compacted the moisture content must be uniform and sufficient to obtain the required compaction. Avoid material segregation. AB must be free from pockets of coarse or fine material.

SECTION 27 CEMENT TREATED BASES
27-1.03E Spreading Treated Mixture
Transport materials mixed at a location off the roadbed as a uniform mixture. Cover the mixture during transport to avoid moisture loss, if ordered. Deposit the mixture on the roadbed at a quantity that provides the specified compacted thickness without spotting, picking up, or shifting the mixture.
Just before depositing plant-mixed or spreading road-mixed CTB, moisten the area to be covered. The area must be kept moist, but not excessively wet.
Avoid material segregation. CTB must be free from pockets of coarse or fine material.
. . .
3. For Type 3 spreading operation, spread the treated mixture with any equipment that will consistently finish the base within the tolerance specified in section 27-1.03F without material segregation.

SECTION 30 RECLAIMED PAVEMENTS
30-1.03 CONSTRUCTION
30-1.03B Equipment
If supplementary aggregate or cement is spread before pulverizing the existing pavement, the pulverizing equipment must produce a uniform mixture without segregation.

30-2.01D(3) Department Acceptance
The Department accepts pulverized roadbed based on:
1. Visual inspection including:
    1.1. Segregation, tearing, and scarring of the finished surface
    1.2. Variance of more than 0.05 foot measured from the lower edge of a 12-foot straightedge
    1.3. Uniform surface texture throughout the work limits
    1.4. Repaired areas
30-2.03E Finishing

The finished surface must be free from segregation, tearing, and scarring, and have a uniform surface texture throughout the work limits.

Maintain the pulverized roadbed surface free of ruts, bumps, indentations, raveling, and segregation. Repair damaged pulverized roadbed with minor HMA.

30-3.01D(3) Department Acceptance
The Department accepts FDR—foamed asphalt based on:
1. Visual inspection for:
    1.1. Segregation, raveling, and loose material

30-4.01D(4) Department Acceptance
The Department accepts FDR—cement based on:
1. Visual inspection for the following:
    1.1. Segregation, raveling, and loose material

SECTION 39 ASPHALT CONCRETE
39-2.01C Construction
39-2.01C(1) General
HMA must be free of:
1. Segregation
2. Coarse or fine aggregate pockets
3. Hardened lumps
4. Marks
5. Tearing
6. Irregular texture

SECTION 40 CONCRETE PAVEMENT
40-1.01D(6) Test Strips
The Engineer selects from 6 to 12 core locations for dowel bars and up to 6 locations for tie bars for each test strip. If you use mechanical dowel bar inserters, the test strip must demonstrate they do not leave voids, segregations, or surface irregularities such as depressions, dips, or high areas.

40-1.03F(4) Stationary Side-Form Construction
Consolidate the concrete without segregation.

40-1.03F(5) Slip form Construction
If you use slip form construction, spread, screed, shape, and consolidate the concrete to the shown cross section with slip form machines and minimal hand work. Slip form paving machines must be equipped with traveling side forms and must not segregate the concrete.

SECTION 49 PILING
49-3.01C Construction
The methods used to place the concrete must prevent segregation.

49-3.02B(2) Concrete

Concrete placed under slurry must:
1. Have a nominal slump equal to or greater than 7 inches. The nominal and maximum slump and penetration specifications in section 90-1.02G(6) do not apply to concrete placed under slurry.
2. Contain at least 675 pounds of cementitious material per cubic yard and be proportioned to prevent excessive bleed water and segregation.

SECTION 51 CONCRETE STRUCTURES
51-1.03D Placing Concrete
51-1.03D(1) General
Thoroughly moisten forms and subgrade with water immediately before placing concrete. Place and consolidate concrete using methods that (1) do not cause segregation of the aggregate and (2) produce dense, homogeneous concrete without voids or rock pockets.

SECTION 55 STEEL STRUCTURES
55-1.02D(6) Unidentified Stock Material
You may use unidentified stock material on non-fracture critical members if:
1. No more than 30,000 pounds is used
2. Unidentified stock material is segregated from all other materials used in the work

SECTION 58 SOUND WALLS
58-2.02D Grout
Mix the grout with enough water to produce a mix consistency suitable for pumping without segregation. The grout must have a slump from 8 to 11 inches.

SECTION 61 GENERAL
61-5 CONCRETE BACKFILL FOR PIPE TRENCHES
61-5.03 CONSTRUCTION
Place concrete backfill in the trench against undisturbed material at the sides and bottom of the trench in a way that prevents (1) floating or shifting of the pipe and (2) voids or segregation of the concrete.

SECTION 70 MISCELLANEOUS DRAINAGE FACILITIES
70-6.03 CONSTRUCTION
Place concrete backfill in the trench as shown. Place against undisturbed material at the sides and bottom of the trench in a manner that prevents (1) floating or shifting of the grated line drain and (2) voids or segregation in the concrete.

SECTION 71 EXISTING DRAINAGE FACILITIES
71-3.01A(4)(c)(v) Pipeliners Pipeliners must be continuous over the entire length of the culvert and must have no visual defect such as foreign inclusions, concentrated ridges, discoloration, pitting, pin holes, cracking or other deformities. The pipeliner must not be over-deflected. There must not be segregation or voids in the grout.

71-3.01C(5)(b) Annular Space Grouting
Grout the entire annular space between the pipeliner and culvert without voids or grout segregation.

SECTION 73 CONCRETE CURBS AND SIDEWALK
73-1.03C Fixed Form Method
Place and compact the concrete without segregation.

SECTION 90 CONCRETE
90-1.02F(2) Storage of Aggregates
When placing the aggregates in storage or moving the aggregates from storage to the weigh hopper of the batching plant, do not use methods that cause either of the following:
1. Segregation, degradation, or the combining of materials of different gradations and result in an aggregate size failing to comply with the gradation specifications at the weigh hopper
2. Excessive particle breakage

90-5 SELF-CONSOLIDATING CONCRETE
90-5.01B Definitions
self-consolidating concrete (SCC): Flowing concrete that is capable of spreading to a level state without segregation and without the use of internal or external vibrators.

Colorado

Q11 response: See Section 401.16 of our specifications.
https://www.codot.gov/business/designsupport/cdot-construction-specifications/2019-construction-specifications/2019-specs-book/2019-division-400
Q13 response: CP 46 - Determination of the gradation of aggregate from a core, see Section 401.16 of the specifications for determining segregation criteria.
https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-fmm/cps/CP-50s/29-cp-58-21

DIVISION 400
PAVEMENTS
SECTION 401
PLANT MIX PAVEMENTS–GENERAL

401.10 Asphalt Pavers.
The asphalt paver shall be equipped with a means of preventing the segregation of the coarse aggregate particles from the remainder of the asphalt plant mix when that mix is carried from the paver hopper back to the paver augers. The means and methods used shall be approved by the paver manufacturer and may consist of chain curtains, deflector plates, or other such devices and any combination of these.

Prior to the start of using the paver for placing plant mix, the Contractor shall submit for approval a full description in writing of the means and methodologies that will be used to prevent asphalt paver segregation. Use of the paver shall not commence prior to receiving approval from the Engineer.

The Contractor shall supply a Certificate of Compliance that verifies that the approved means and methods used to prevent asphalt paver segregation have been implemented on all pavers used on the project.

401.15 Mixing.
Storing or holding of asphalt mixture will be permitted provided the characteristics of the mixture are not altered. If storing or holding of the mixture causes segregation, excessive heat loss, or adversely affects the quality of the finished product, corrective action shall be taken. Unsuitable mixture shall be disposed of at the Contractor's expense.

401.16 Spreading and Finishing.
The asphalt mixture shall be transported and placed on the roadway without segregation. All segregated areas behind the paver shall be removed immediately upon discovery. The segregated material shall be replaced with specification material before the initial rolling has taken place. If more than 50 square feet of segregated pavement is ordered removed and replaced in any continuous 500 linear feet of paver width laydown, operations shall be discontinued until the source of the segregation has been found and corrected.
If at any time, the Engineer observes segregated areas of pavement, he will notify the Contractor immediately.
After rolling, segregated areas will be delineated by the Engineer and evaluated as follows:
(1) The Engineer will delineate the segregated areas to be evaluated and inform the Contractor of the location and extent of these areas within two calendar days, excluding weekends and holidays, of placement.
(2) In each segregated area or group of areas to be evaluated, the Contractor shall take five 10 inch cores at random locations designated by the Engineer. In accordance with CP 75, the Contractor shall also take five 10 inch cores at random locations designated by the Engineer in non-segregated pavement adjacent to the segregated area. These cores shall be within 30 feet of the boundary of the segregated area and in the newly placed pavement. The coring shall be in the presence of the Engineer and the Engineer will take immediate possession of the cores. The Contractor may take additional cores at the Contractor's expense.
(3) Gradation of the aggregate of the cores will be determined by CDOT in accordance with CP 46.
(4) The core aggregate gradations from the segregated area will be compared to the core aggregate gradations of the corresponding non-segregated area.
(5) Two key sieves of the core gradations from the segregated area will be compared to the core gradations from the corresponding non-segregated area to determine the difference. If differences for both key sieves exceed the allowable difference specified in the table below, the area is segregated.

SEGREGATION DETERMINATION

Mix Grading	Key Sieves	Allowable Difference, %
SX	2.36 mm (#8), 4.75 mm (#4)	9
X	2.36 mm (#8), 4.75 mm (#4)	9

(6) Segregated areas in the top lift shall be removed and replaced, full lane width, at the Contractor's expense. The Engineer may approve a method equivalent to removal and replacement that results in a non-segregated top lift. Segregated areas, in lifts below the top lift that are smaller than 50 square feet per 100 linear feet of lane width shall be corrected by the Contractor at the Contractor's expense in a manner acceptable to the Engineer. Segregated areas larger than 50 square feet per 100 linear feet of lane width in any lift shall be removed and replaced, full lane width, by the Contractor at the Contractor's expense.

If the area is determined to be segregated, the coring shall be at the expense of the Contractor. If the area is determined to be nonsegregated, the Engineer will reimburse the Contractor $2,000 for obtaining the ten cores.

The Engineer will perform a systematic segregation check in accordance with CP 58 as early in the project as is feasible to determine if temperature segregation problems exist. Temperature segregation will be of concern on the project if, across the width of the mat, temperatures vary by 25 °F or more. Densities will not need to be taken in the systematic segregation check. The Engineer will discuss the temperature findings of the systematic segregation check with the Contractor.

The Engineer may evaluate the HMA for low density due to temperature segregation whenever industry best practices, as detailed on Form 1346, are not being followed or the Engineer suspects temperature segregation is occurring. The Engineer will first meet with the Contractor to discuss the paving practices that are triggering the temperature investigation. Areas across the mat, excluding the outside 1 foot of both edges of the mat, that are more than 25 °F cooler than other material across the width may be marked for density testing. Material for temperature comparison will be evaluated in 3-foot intervals behind the paver across the width of the mat. The material shall be marked and tested in accordance with CP 58. If four or more areas within a lot of 500 tons have densities of less than 93 percent of the material's maximum specific gravity for SMA mixes or less than 92 percent of the material's maximum specific gravity for all other HMA mixes, a 5 percent price disincentive will be applied to the 500 ton lot. The 500 ton count begins when the Engineer starts looking for cold areas, not when the first cold area is detected. This price disincentive will be in addition to those described in Sections 105 and 106. Only one area per delivered truck will be counted toward the number of low density areas. Temperature segregation checks will be performed only in areas where continuous paving is possible.

SECTION 406
COLD ASPHALT PAVEMENT (RECYCLE)

406.06 Spreading.
If segregation occurs behind the paver, the Contractor shall make changes in equipment, operations, or both to eliminate the segregation.

406.08 Recycling Train.
The recycling agent shall be applied through a separate mixing machine capable of mixing the pulverized material and the recycling agent to a homogeneous mixture, and placing the mixture in a windrow. The mixture shall be placed in a windrow in a manner that prevents segregation.

406.09 Paver. The recycled material shall be placed with a self-propelled asphalt paver meeting the requirements of subsection 401.10, except that the screed shall not be heated. The mixed material shall be spread in one continuous pass, without segregation, to the lines and grades established on the plans.

Colorado procedures and forms:
https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/jsa/cp-l-methods
CP 75 – coring – selecting sites and taking cores
CP 58 – Standard Method of Test for Detecting and Measuring Temperature Segregation of HMA
CP 46 – gradation – sieve analysis
systematic segregation check in accordance with CP 58 – temperature segregation procedure and form
CP 17 – Hot Mix Asphalt Test Result Verification and Dispute Resolution. Lengthy document
https://www.codot.gov/library/forms/cdot-forms-by-number
Engineer may evaluate the HMA on Form 1346, HMA Segregation Data. Designed to monitor temperatures. Includes list of countermeasures.

CP 46 (next page):
https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/jsa/cp-l-methods/MJSA-CP-46%20%2806-22-09%29.pdf

COLORADO DEPARTMENT OF TRANSPORTATION

JOB SAFETY ANALYSIS

Activity Name: Gradation of Aggregate in a Core			**Activity Number:** CP-46	
Activity Description & Purpose: Run sieve analysis to determine aggregate particle size distribution from a core. Core preparations includes sample transport from receiving area, heating, and splitting to test sample size and determining the asphalt cement content of HMA sample by ignition method.				
Date Prepared: April 1, 2009				**PPE Required**
Typical Equipment		**Typical Crew Size:**	**Typical Material**	Safety glasses/Hardtoe boots/Heat resistant gloves/Heat resistant apron/Long sleeve cotton shirt or elbow-length heat resistant gloves
Description	Class Code	(Crew sizes may vary due to different conditions throughout the state).	Description / Class Code	
See associated test procedure			See associated test procedure	

Sequence of Job Tasks	Potential Hazards	Safe Job Procedures	Never
Reference the Following JSAs:			
CP-31			
CP-55			
CPL-5120			
Coring Operations Process			
CP-46 (Unique Tasks)			
1-Clean and Separate Cores	1-Pinched Fingers	1 - Observe hand/finger placement when lifting or setting-down containers, use caution with hammer and	
	2-Particles in eyes	2 - Wear all personal protective equipment.	
2.- Heat cores and template	1 - Burns	1 - Wear all personal protective equipment.	handle hot materials without gloves
3.- Remove outer layer of cores	1 - Burns	1 - Wear all personal protective equipment.	handle hot materials without gloves

Distribution:
CDOT Safety Manual

CDOT Form # 1370 05/06

Q12 response: CP 58 - Thermal Segregation
https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-fmm/cps/CP-50s/29-cp-58-21

Colorado Procedure 58-07
Standard Method of Test for
Detecting and Measuring
Temperature Segregation of HMA

1. SCOPE

1.1 This method describes the procedure for detecting and measuring temperature segregation of HMA using a handheld temperature device.

2. REFERENCED DOCUMENTS

2.1 CP 81 Density and Percent Relative Compaction of In-Place Bituminous Pavement by the Nuclear Method

3. APPARATUS

3.1 *Handheld Temperature Device* – An infrared temperature gun or infrared camera that is capable of measuring in one degree or finer increments between the temperatures of 150° to 400° F. For best clarity in readings, it is suggested that the temperature gun have a distance-to-spot size ratio (D:S) of 30:1 or greater.
3.2 Paint, grease crayon, or some other tool to mark locations to be tested for density.
3.3 Tape measure long enough to span the width of the paving area.

4. PROCEDURE

4.1 Mark the start of the area that will be examined. The tonnage of the area can be calculated in length by using 110 lbs/yd^2/inch or can be found by tracking asphalt tickets. See Figure 58-1.
4.2 Scan the paving area with the hand-held temperature device looking for an area that is 25°F cooler than other areas across the width of the mat. Do not stand on or walk on the paving area. Stand adjacent to the paving area, behind the paver but ahead of the breakdown roller, and scan slowly across the width of the mat excluding the outer one foot on each side of the mat. Move three feet forward and repeat scanning. Repeat as needed.
4.3 If an area is 25°F cooler than other areas across the width of the mat, mark the location on the edge of the mat and use a tape measure to locate the cooler area. Record on CDOT Form 1346.
4.4 Following finish rolling, locate the cooler area and find the density of the area per CP 81. Record on CDOT Form 1346.

5. REPORT

5.1 CDOT Form 1346, HMA Segregation Data, will serve as the report document.

In Figure 58-1 below, the tester performed the temperature segregation check correctly. A start was established and 500 tons were checked for temperature segregation. Three cool areas were found in the 500-ton temperature segregation check.

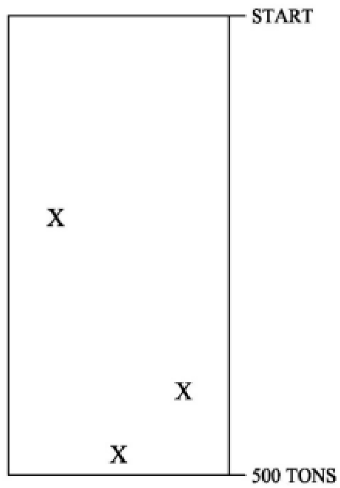


Figure 58-1: Temperature Segregation Study Done Correctly

In Figure 58-2 below, the tester did not perform the temperature segregation check correctly. A start was established and the tester went about 400 yards finding just two cool areas. He then restarted the temperature segregation check at the second cool area by establishing a new 500-ton test section. This resulted in finding five cool areas over the next 500 tons. This is incorrect.

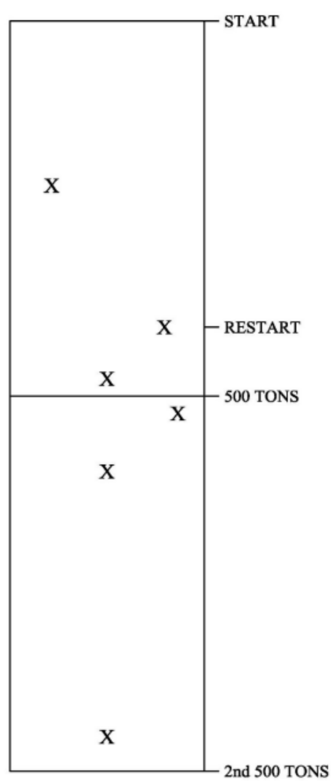


Figure 58-2: Temperature Segregation Study Done Incorrectly

Form 1346

COLORADO DEPARTMENT OF TRANSPORTATION

HMA SEGREGATION DATA

Contract ID	Mix design	Region	Date	Ave. lift thickness

Paving contractor	HMA grading (S, SX, SMA)	Gyrations (50, 75, 100)	Binder grade (58-25, 64-22, etc.)

Truck type	Delivery system make and model	Paver make and model

Look for a temperature difference of 25°F or more across the width of the mat at 3 foot intervals behind the paver. Exclude outside 1 foot of mat.

Only one area per delivered truck will be counted toward the number of low density areas.

Mark where you start taking readings. There's no penalty unless there are 4 areas within 500 tons of mix, so tonnage must be tracked.

If you don't track the tickets and want to calculate tonnage, use 110 pounds per square yard per inch.

Tonnage of starting ticket:______________________ or mark for start of study:____________________________

Approximate length of paving per truck: Length in feet = (tonnage on truck)/[(width in feet)(depth in inches)(.0061)]

Industry best practices are listed on the back of this worksheet.

Temperature readings are taken before the breakdown roller compacts the area.

Identifying mark of "cold" area	Location of "cold" area from CL or edge of pavement	Station	Temperature of "cold" area	Temperature of adjacent "hot" area	% Relative Compaction of "cold" area (from CDOT Form #428)	Notes

Notes:

CDOT Tester (print name)	Title	Phone number (include area code)	CDOT Supervisor

Previous editions are obsolete and may not be used. Page 1 of 2 CDOT Form #1346 4/14

Best Practices for Minimizing Segregation

1. Aggregate Stockpiles

A. Build in layers.
B. Avoid any procedure that allows aggregate to be pushed or dumped over the side of a stockpile.
C. Separate to prevent intermingling.
D. Aggregate Handling:
(1) Loader operator works full face of stockpile.
(2) Install dividers on cold feed bins to prevent material from flowing into an adjacent bin.
(3) Do not pile aggregate so high that it flows over the dividers.

2. Loading Surge Silo: (If plant has batcher or gob hopper at top of silo.)

A. Adjust conveying devices to deposit material in center of batcher or gob hopper.
B. Keep gates on batcher or gob hopper closed unless dropping load of mix.
C. Close gates on batcher or gob hopper before it is empty to prevent material from dribbling into silo.

3. Loading Trucks:

A. Keep gates on bottom of silo closed so material does not dribble into trucks.
B. Take care to center trucks (Left to Right) when loading.
C. Consider loading trucks in multiple drops with first drop at rear, second drop at front, and then alternate dumps.
D. If the mix is prone to segregate you should avoid loading trucks by slowly driving forward while dropping mix.

4. Dumping Trucks:

A. To provide a surge of material to the paver, when using end dump trucks, the box should be raised until the mix moves to the rear before opening the tailgate.
B. If any mix is spilled on the roadway in front of the paver while dumping the truck, this mix should be removed from the roadway before the paver starts forward.

5. Laydown Operations:

A. Only dump wings of the hopper at the end of the day and then waste this material. Do not knock cold material off the wings and into the hopper.
B. To provide consistent flow of material to the screed, the operator should avoid gradual deceleration or gradual acceleration.
The paver should be stopped and started quickly at normal operating speed.
C. Keep hopper more than half full at all times.
D. Auger height should be adjusted so bottom of auger is at least two (2) inches above the finished surface of the mat.
E. Adjust feed sensors to keep material near the center of the auger at all times.
F. Correctly adjust the lead and trail crown of the screed so that the surface of the HMA behind the paver is uniform in appearance and texture.
G. Install reverse fins at the center of auger to tuck the proper amount of material under the gear box.
H. Adjust flow gates at rear of the hopper so that:
(1) The slat conveyors run continuously.
(2) The amount of material furnished to the augers allows them to run nearly 100% of the time.
I. The risk of causing thermal segregation is increased when paving in cooler temperatures.

6. Windrow Elevators:

A. When using pick up machines, they should be adjusted such that all the HMA is removed from the surface.

Form 428 for CP 81

COLORADO DEPARTMENT OF TRANSPORTATION **NUCLEAR DENSITY TEST of HMA** **CP 81**	Project No.	Region	Contract ID
	Project Location		
	Form #43 No.		Grading
Tester (print name)	Company Name or CDOT		Gauge ID

Sample ID							
Test #	IA #						
Sample ID (For IAT)							
Date of test							
Standard Count							
Ave. Daily Rice							
Station							
Offset							
Course/Lift							
Backscatter 4, 1 minute readings	Wet Density #1						
	Wet Density #2						
Turn Gauge 180°	Wet Density #3						
	Wet Density #4						
Sum of the Wet Densities							
Average Wet Density							
Correction Factor (#469) **PCF**							
Adjusted Wet Density							
Ave. Daily Rice X 62.4 (**PCF**)							
% Compaction							

Sample ID					
Test #	IA #				
Sample ID (For IAT)					
Date of test					
Standard Count					
Ave. Daily Rice					
Station					
Offset					
Course/Lift					
Backscatter 4, 1 minute readings	Wet Density #1				
	Wet Density #2				
Turn Gauge 180°	Wet Density #3				
	Wet Density #4				
Sum of the Wet Densities					
Average Wet Density					
Correction Factor (#469)					
Adjusted Wet Density					
Ave. Daily Rice X 62.4 (**PCF**)					
% Compaction					

Place IA stamp here:

Tested by (print name)	Sampled by (print name)	Company Name or CDOT

Previous editions are obsolete and may not be used.

CDOT Form #428 4/18

Q18 response: The Contractor can submit a dispute and follow the processes outlined in Section 105.22 of our specifications. https://www.codot.gov/business/designsupport/cdot-construction-specifications/2019-construction-specifications/2019-specs-book/2019-division-100

p. 1-42 through 1-45

105.22 Dispute Resolution. Subsections 105.22, 105.23, and 105.24 detail the process through which the parties (CDOT and the Contractor) agree to resolve any issue that may result in a dispute. The intent of the process is to resolve issues early, efficiently, and as close to the project level as possible. Figure 105-1 outlines the process. Specified time frames may be extended by mutual agreement of the Engineer and the Contractor. In these subsections, when a time frame ends on a Saturday, Sunday or holiday, the time frame shall be extended to the next scheduled work day.

An issue is a disagreement concerning contract price, time, interpretation of the Contract, or all three between the parties at the project level regarding or relating to the Contract. Issues include, but are not limited to, a disagreement resulting from a delay, a change order, another written order, or an oral order from the Project Engineer, including any direction, instruction, interpretation, or determination by the Project Engineer, interpretations of the Contract provisions, plans, or specifications or the existence of alleged differing site conditions.

The Contractor shall be barred from any administrative, equitable, or legal remedy for any issue which meets either of the following criteria:

(1) The Contractor did not bring the issue to the Project Engineer's attention in writing within 20 days of the Contractor being aware of the issue.

(2) The Contractor fails to continually (weekly or otherwise approved by both parties) work with CDOT towards a resolution.

A dispute is an issue which the Contractor and CDOT have not been able to resolve and for which the Contractor submits a written formal notice of dispute in accordance with subsection 105.22(b).

A claim is a dispute not resolved at the Resident Engineer level or resolved after a DRB recommendation.

The term "merit" refers to the right of a party to recover on a claim or dispute, irrespective of quantum, based on the substance, elements, and grounds of that claim or dispute. The term "quantum" refers to the quantity or amount of compensation or time deserved when a claim or dispute is found to have merit.

Disputes from subcontractors, material suppliers, or any other entity not party to the Contract shall be submitted through the Contractor. Review of a pass-through dispute does not create privity of Contract between CDOT and the subcontractor.

An audit may be performed by the Department for any dispute. Refer to subsection 105.24 for audit requirements.

If CDOT does not respond within the specified timelines, the Contractor may advance the dispute to the next level.

When the Project Engineer is a Consultant Project Engineer, actions, decisions, and determinations specified herein as made by the Project Engineer shall be made by the Resident Engineer.

The dispute resolution process set forth in this subsection shall be exhausted in its entirety prior to initiation of litigation or arbitration. Failure to comply with the requirements set forth in this subsection shall bar either party from any further administrative, equitable, or legal remedy. If a deadline is missed that does not prejudice either party, further relief shall be allowed.

All written notices of dispute shall be submitted within 30 days of date of the Project Engineer's Final Acceptance letter; see subsection 105.21(b).

When a project has a landscape maintenance period, the Project Engineer will grant partial acceptance in accordance with subsection 105.21(a). This partial acceptance will be project acceptance of all the construction work performed prior to this partial acceptance.

All disputes and claims related to the work in which this partial acceptance is granted shall be submitted within 30 days of the Project Engineer's partial acceptance.

Should the Contractor's dispute use the Total Cost approach for calculating damages, damages will be determined by subtracting the contract amount from the total cost of performance. Should the Contractor's dispute use the Modified Total Cost approach for calculating damages, if the Contractor's bid was unrealistic in part, and/or some of its costs were unreasonable and/or some of its damages were caused by its own errors, those costs and damages will be deducted from the total cost of performance to arrive at the Modified Total Cost. The Total Cost or Modified Total Cost basis for calculating damages shall not be available for any disputes or claims seeking damages where the Contractor could have kept separate cost records at the time the dispute arose as described in subsection 105.22(a).

(a) Document Retention. The Contractor shall keep full and complete records of the costs and additional time incurred for each dispute for a period of at least three years after the date of final payment or until dispute is resolved, whichever is more. The Contractor, subcontractors, and lower tier subcontractors shall provide adequate facilities, acceptable to the Engineer, for an audit during normal business hours. The Contractor shall permit the Engineer or Department auditor to examine and copy those records and all other records required by the Engineer to determine the facts or contentions involved in the dispute. The Contractor shall identify and segregate any documents or information that the Contractor considers particularly sensitive, such as confidential or proprietary information. Throughout the dispute, the Contractor and the Project Engineer shall keep complete daily records of extra costs and time incurred, in accordance with the following procedures:

    (1) Daily records shall identify each operation affected, the specific locations where work is affected, and the potential effect to the project's schedule. Such records shall also reflect all labor, material, and equipment applicable to the affected operations.

    (2) On the first work day of each week following the date of the written notice of dispute, the Contractor shall provide the Project Engineer with the daily records for the preceding week. If the Contractor's records indicate costs greater than those kept by the Department, the Project Engineer will meet with the Contractor and present his records to the Contractor at the meeting. The Contractor shall notify the Engineer in writing within three work days of any inaccuracies noted in, or disagreements with, the Department's records.

(b) Initial Dispute Resolution Process. To initiate the dispute resolution process, the Contractor shall provide a written notice of dispute to the Project Engineer upon the failure of the Parties to resolve the issue through negotiation. Disputes will not be considered unless the Contractor has first complied with specified issue resolution processes such as those specified in subsections 104.02, 106.05, 108.08(a), and 108.08(d).

    The Contractor shall supplement the written notice of dispute within 15 days with a written Request for Equitable Adjustment (REA) providing the following:

    (1) The date of the dispute.

    (2) The nature of the circumstances which caused the dispute.

    (3) A detailed explanation of the dispute citing specific provisions of the Contract and any basis, legal or factual, which support the dispute.

(4) If any, the estimated quantum, calculated in accordance with methods set forth in subsection 105.24(b)12., with supporting documentation.

(5) An analysis of the progress schedule showing the schedule change or disruption if the Contractor is asserting a schedule change or disruption. This analysis shall meet the requirements of subsection 108.08(d).

The Contractor shall submit as much information on the quantum and impacts to the Contract time as is reasonably available with the REA and then supplement the REA as additional information becomes available. If the dispute escalates to the DRB process, neither party shall provide or present to the DRB any issue or any information that was not contained in the REA and fully submitted in writing to the Project Engineer and Resident Engineer during the subsection 105.22 process.

(c) Project Engineer Review. Within 15 days after receipt of the REA, the Project Engineer will meet with the Contractor to discuss the merits of the dispute. Within seven days after this meeting, the Project Engineer will issue a written decision on the merits of the dispute.

The Project Engineer will either deny the merits of the dispute or notify the Contractor that the dispute has merit. This determination will include a summary of the relevant facts, Contract provisions supporting the determination, and an evaluation of all scheduling issues that may be involved.

If the dispute is determined to have merit, the Contractor and the Project Engineer will determine the adjustment in payment, schedule, or both within 30 days. When a satisfactory adjustment is determined, it shall be implemented in accordance with subsections 106.05, 108.08, 109.04, 109.05 or 109.10 and the dispute is resolved.

If the Contractor accepts the Project Engineer's denial of the merits of the dispute, the dispute is resolved and no further action will be taken. If the Contractor does not respond in seven days, it will be assumed he has accepted the denial. If the Contractor rejects the Project Engineer's denial of the merits of the dispute or a satisfactory adjustment of payment or schedule cannot be agreed upon within 30 days, the Contractor may further pursue resolution of the dispute by providing written notice to the Resident Engineer within seven days, according to subsection 105.22(d).

(d) Resident Engineer Review. Within seven days after receipt of the Contractor's written notice to the Resident Engineer of unsatisfactory resolution of the dispute, the Project Engineer and Resident Engineer will meet with the Contractor to discuss the dispute. Meetings shall continue weekly for a period of up to 30 days and shall include a Contractor's representative with decision authority above the project level.

If these meetings result in resolution of the dispute, the resolution will be implemented in accordance with subsections 108.08, 109.04, 109.05, or 109.10 and the dispute is resolved.

If these meetings do not result in a resolution or the participants mutually agree that they have reached an impasse, the dispute shall be presented to the Dispute Review Board in accordance with subsection 105.23.

Connecticut

SECTION 4.06 BITUMINOUS CONCRETE

4.06.01—Description: Work under this Section shall include the production, delivery and placement of a non-segregated, smooth and dense bituminous concrete mixture brought to proper grade and cross section. This Section shall also include the method and construction of longitudinal joints. The Contractor shall furnish ConnDOT with a Quality Control Plan (QCP) as described in Article 4.06.03.

The following terms as used in this specification are defined as:
Segregation: A non-uniform distribution of a bituminous concrete mixture in terms of gradation, temperature, or volumetric properties.
3. Paving Equipment:
Pavers: Each paver shall have a receiving hopper with sufficient capacity to provide for a uniform spreading operation and a distribution system that places the mix uniformly, without segregation. The paver shall be equipped with and use a vibratory screed system with heaters or burners. The screed system shall be capable of producing a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture. Pavers with extendible screed units as part of the system shall have auger extensions and tunnel extenders as necessary. Automatic screed controls for grade and slope shall be used at all times unless otherwise authorized by the Engineer. The controls shall automatically adjust the screed to compensate for irregularities in the preceding course or existing base. The controls shall maintain the proper transverse slope and be readily adjustable, and shall operate from a fixed or moving reference such as a grade wire or floating beam.

6. Spreading and Finishing of Mixture:
Placement: The bituminous concrete mixture shall be placed and compacted to provide a smooth, dense surface with a uniform texture and no segregation at the specified thickness and dimensions indicated in the plans and specifications.
Surface Requirements: The pavement surface of any lift shall meet the following requirements for smoothness and uniformity. Any irregularity of the surface exceeding these requirements shall be corrected by the Contractor.

a) Smoothness: Each lift of the surface course shall not vary more than 1/4 in from a Contractor-supplied 10 ft straightedge. For all other lifts of bituminous concrete, the tolerance shall be 3/8 in. Such tolerance will apply to all paved areas.
b) Uniformity: The paved surface of the mat and joints shall not exhibit segregation, rutting, cracking, disintegration, flushing or vary in composition as determined by the Engineer.

Delaware

Only mention of segregation in asphalt:
1014.16 Silo Storage Systems.
Convey the mixture from the plant to the storage system without a reduction in temperature, the segregation of the mix, or the oxidation of the asphalt.

District of Columbia

106 CONTROL OF MATERIALS
C. MINIMUM CONTRACTOR PROCESS QUALITY CONTROL REQUIREMENTS FOR BITUMINOUS MATERIALS 1. All Types Of Plants

a. Stockpiles
i. Determine gradation of all incoming aggregates as per AASHTO T-27 (Weekly or as directed by the Chief Engineer)
ii. Inspect stockpiles for separation, contamination, segregation, etc. (Daily)

904 BITUMINOUS EQUIPMENT
904.01 BITUMINOUS MIXING PLANTS

C. SURGE AND STORAGE BINS - The Contractor may elect to store hot mixed bituminous concrete in a surge or storage bin provided said bin has received prior evaluation and approval by the Engineer. . . .
Mixtures that the Engineer determines visually to be segregated will be rejected.
. . .
The system shall be capable of conveying the hot mix from the Plant to the storage bins and storing the hot-mix without a loss in temperature, segregation of the mix or oxidation of the mix. Storage and surge bins shall be designed in such a manner as to prevent segregation of the hot mix during discharge from the conveyor into the bins and shall be equipped with discharge gates that will not cause segregation of the hot mix while loading the mix into the trucks.

905.02 MIXERS, PAVERS, AND DELIVERY EQUIPMENT
B. CENTRAL PLANT - The mixer shall be of an approved design of the batch type and have a rated capacity of not less than 27 cubic feet of mixed concrete. The mixer shall be capable of combining the aggregates, cement and water into a thoroughly mixed and uniform mass within the specified mixing period, and of discharging the mixture without segregation.

905.05 SPREADING MACHINES
The apparatus shall be capable of spreading the concrete to both the depth specified for reinforcement and the full thickness of the slab without segregation and without interfering with the joints or reinforcement.

Florida

SECTION 320 HOT MIX ASPHALT - PLANT METHODS AND EQUIPMENT
320-2 Quality Control (QC) Requirements.
320-2.1 Minimum Producer QC Requirements: Perform as a minimum the following activities:
1. Stockpiles:
   a. Assure materials are placed in the correct stockpile;
   b. Assure good stockpiling techniques;
   c. Inspect stockpiles for separation, contamination, segregation, and other similar items;

. . .
320-3.4 Aggregate: Meet the following requirements:
320-3.4.1 Stockpiles:
Form and maintain stockpiles in a manner that will prevent segregation. If a stockpile is determined to be segregated, discontinue the use of the material on the project until the appropriate actions have been taken to correct the problem.

SECTION 330 HOT MIX ASPHALT - GENERAL CONSTRUCTION REQUIREMENTS
330-2 Quality Control (QC) Requirements.
330-2.1 Minimum QC Requirements: Perform as a minimum, the following activities necessary to maintain process control and meet Specification requirements:

4. Pavement Texture: Monitor the pavement texture to minimize pavement segregation. Use density gauges, infrared temperature measurement devices, or roadway cores at the beginning of each day's production, and as necessary, both at truck exchanges and during normal paving operations.

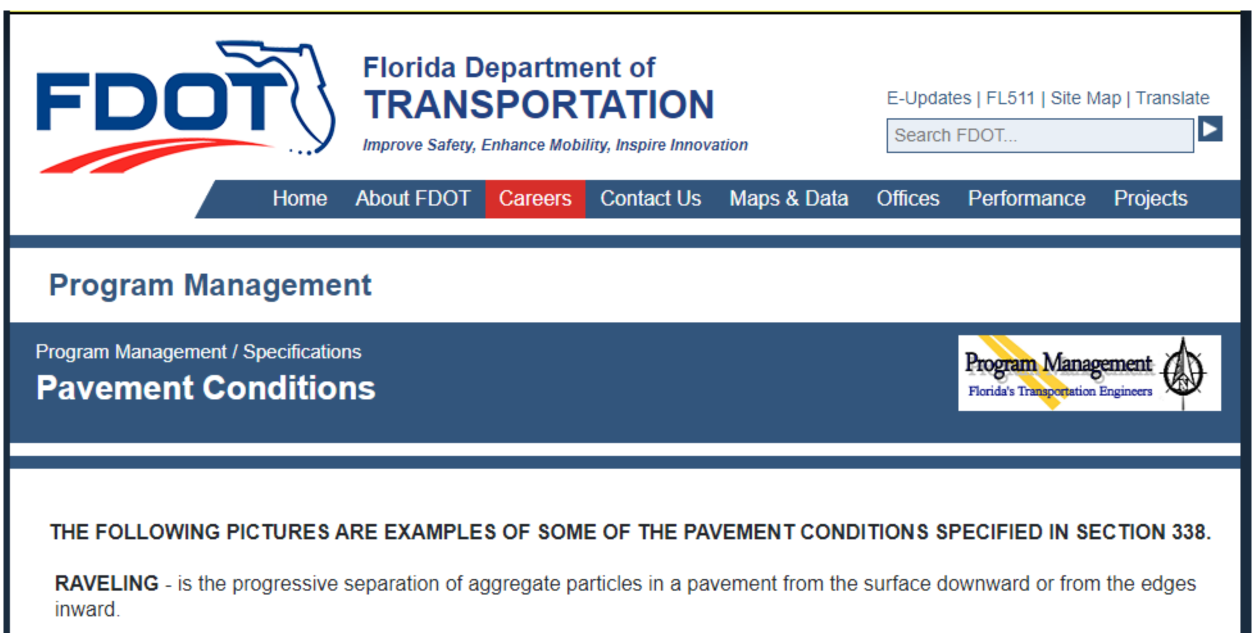
330-9 Surface Requirements.
330-9.2 Texture of the Finished Surface of Paving Layers: Produce a finished surface of uniform texture and compaction with no pulled, torn, raveled, crushed or loosened portions and free of segregation, bleeding, flushing, sand streaks, sand spots, or ripples. Some examples of pavement deficiencies are displayed at the following URL: https://www.fdot.gov/programmanagement/Implemented/URLinSpecs/Pavement.shtm. Address any pavement not meeting the requirements of this specification in accordance with 330-9.5.

For dense-graded structural and dense-graded friction course mixtures, in areas not defined as density testing exceptions per 334-5.1.2, obtain for the Engineer, three 6-inch diameter roadway cores at locations visually identified by the Engineer to be segregated. For 275 January 2021 areas that the Engineer identifies as being segregated, obtain and submit cores within 30 days of notification. The Engineer will determine the density of each core in accordance with FM 1- T166 and calculate the percent Gmm of the segregated area using the average Gmb of the roadway cores and the QC sublot Gmm for the questionable material. If the average percent Gmm is less than 89.5, address the segregated area in accordance with 330-9.5.

330-9.5 Unacceptable Pavement:

330-9.5.1 Corrections: Address all areas of unacceptable pavement at no cost to the Department. Retest all corrected areas and assure the requirements of these Specifications are met. 330-9.5.1.1 Structural Layers: Correct all deficiencies, as defined in the Specifications, in the Type SP structural layers by removing and replacing the full depth of the layer, extending a minimum of 50 feet on both sides (where possible) of the defective area for the full width of the paving lane.

https://www.fdot.gov/programmanagement/Implemented/URLinSpecs/Pavement.shtm



BLEEDING - is the upward movement of liquid asphalt resulting in the formation of a film of asphalt on the surface.

SLIPPAGE - is the movement between layers when none should exist. Picture illustrates classical U pattern.

POT HOLES

DELAMINATION

(photos of each included)

Georgia

Section 400-Hot Mix Asphaltic Concrete Construction

400.1.01 Definitions

Segregated Mixture: Mixture lacking homogeneity in HMA constituents of such a magnitude that there is a reasonable expectation of accelerated pavement distress or performance problems. May be quantified by measurable changes in temperature, gradation, asphalt content, air voids, or surface texture.

400.1.03 Submittals

B. Paving Plan

If segregation is detected, submit a written plan of measures and actions to prevent segregation. Work will not continue until the plan is submitted to and approved by the Department.

400.2.01 Delivery, Storage, and Handling

Segregation, lumpiness, drain-down, or stiffness of stored mixture is cause for rejection of the mixture. The Engineer will not approve using a storage or surge bin if the mixture segregates, loses excessive heat, or oxidizes during storage.

400.3.02 Equipment

B. Plant Equipment

3. Surge- and Storage-Systems

c. Ensure surge and storage systems do not contribute to mix segregation, lumpiness, drain-down, or stiffness.

5. Materials Transfer Vehicle (MTV)

b. Ensure the MTV and conventional paving equipment meet the following requirements:

1) MTV

- Provides to the paver a homogeneous, non-segregated mixture of uniform temperature with no more than 20 °F (11 °C) difference between the highest and lowest temperatures when measured transversely across the width of the mat in a straight line at a distance of one foot to twenty-five feet (0.3 m to 7.6 m) from the screed while the paver is operating. Ensure that the MTV is capable of providing the paver a consistent material flow that is sufficient to prevent the paver from stopping between truck exchanges.

400.3.05 Construction

F. Perform Spreading and Finishing

Spread and finish the course as follows:

10. Do not use mixture with any of these characteristics:

- Segregated
- Nonconforming temperature
- Deficient or excessive asphalt cement content
- Otherwise unsuitable to place on the roadway in the work

11. Remove and replace mixture placed on the roadway that the Engineer determines has unacceptable blemish levels from segregation, raveling, streaking, pulling and tearing, or other deficient characteristics. Replace with acceptable mixture at the Contractor's expense. Do not continually place mixtures with deficiencies.

400.3.06 Quality Acceptance

E. Segregated Mixture

Prevent mixture placement yielding a segregated mat by following production, storage, loading, placing, and handling procedures. Ensure needed plant modifications and provide necessary auxiliary equipment. (See Subsection 400.1.01, "Definitions.")

If the mixture is segregated in the finished mat, the Department will take actions based on the degree of segregation. The actions are described below.

1. Unquestionably Unacceptable Segregation

   When the Engineer determines the segregation in the finished mat is unquestionably unacceptable, follow these measures:

   a. Suspend Work and require the Contractor to take positive corrective action. The Department will evaluate the segregated areas to determine the extent of the corrective work to the in-place mat as follows:
      Perform extraction and gradation analysis by taking 6 in (150 mm) cores from typical, visually unacceptable segregated areas.
      Determine the corrective work according to Subsection 400.3.06.E.3.
   b. Require the Contractor to submit a written plan of measures and actions to prevent further segregation. Work will not continue until the plan is submitted to and approved by the Department.
   c. When work resumes, place a test section not to exceed 500 tons (500 Mg) of the affected mixture for the Department to evaluate. If a few loads show that corrective actions were not adequate, follow the measures above beginning with step 1.a. above. If the problem is solved, Work may continue.

2. Unacceptable Segregation Suspected

   When the Engineer observes segregation in the finished mat and the work may be unacceptable, follow these measures:

   a. Allow work to continue at Contractor's risk.
   b. Require Contractor to immediately and continually adjust operation until the visually apparent segregated areas are eliminated from the finished mat. The Department will immediately investigate to determine the severity of the apparent segregation as follows:
      - Take 6 in (150 mm) cores from typical areas of suspect segregation.
      - Test the cores for compliance with the mixture control tolerances in Section 828.

   When these tolerances are exceeded, suspend work for corrective action as outlined in Subsection 400.3.06.E.3.

3. Corrective Work

a. Remove and replace (at the Contractor's expense) any segregated area where the gradation on the control sieves is found to vary 10 percent or more from the approved job mix formula, the asphalt cement varies 1.0% or more from the approved job mix formula, or if in-place air voids exceed 13.5% based on GDT 39. The control sieves for each mix type are shown in Subsection 400.5.01.B "Determine Lot Acceptance."

b. Subsurface mixes. For subsurface mixes, limit removal and replacement to the full lane width and no less than 10 ft. (3 m) long and as approved by the Engineer.

c. Surface Mixes. For surface mixes, ensure that removal and replacement is not less than the full width of the affected lane and no less than the length of the affected areas as determined by the Engineer.

Surface tolerance requirements apply to the corrected areas for both subsurface and surface mixes

Section 402-Hot Mix Recycled Asphaltic Concrete
402.3 Construction Requirements
402.3.02 Equipment
D. Feeders and Conveyors
Equip plants with an interlocking system of feeders and conveyors that synchronize the RAP or RAS material flow with the virgin aggregate flow. Ensure that the electronic controls track the flow rates indicated by the belt weighing devices and develop the signal to automatically maintain the desired ratio at varying production rates. Design the RAP or RAS feeder bins, conveyor system, and auxiliary bins (if used) to prevent RAP material from segregating and sticking.

Section 403-Hot In-Place Recycled Asphaltic Concrete
403.2.01 Delivery, Storage, and Handling
A. Aggregate Storage
Store or stockpile mineral aggregates in a manner that will prevent segregation, mixing of the various sizes, and contamination with foreign materials

403.3.05 Construction
D. Application
Control placement of the mixture to produce a surface true to line, grade, and cross-slope with a uniform surface texture free of segregation, lumps, or other unacceptable streaks or blemishes as determined by the Engineer. Ensure the mixture meets the acceptance requirements for mixture quality, compaction, smoothness, and thickness as specified in Subsection 403.3.06.

Section 428-Micro Surfacing
428.2.01 Delivery, Storage, and Handling
A. Aggregate Storage
Store or stockpile mineral aggregates in a manner that will prevent segregation, mixing of the various materials or sizes, and contamination with foreign materials. Do not use construction equipment on, or to ramp the stockpiled aggregate. Pass the aggregate over a scalping screen immediately before transferring it to the micro-surfacing mixing machine to remove oversized material.

Hawaii

DIVISION 400 – PAVEMENTS
SECTION 401 – HOT MIX ASPHALT PAVEMENT
Text not searchable.

DIVISION 400 - PAVEMENTS

SECTION 401 - HOT MIX ASPHALT (HMA) PAVEMENT

401.03 Construction.

(E) Spreading and Finishing.

Deposit HMA in a manner that minimizes segregation. Raise truck beds with tailgates closed before discharging HMA.

Idaho

SECTION 415 – MICROSURFACING
415.03 Construction Requirements.
J. Mix Stability. Prevent premature breaking of the emulsion in the spreader box. Ensure the mixture is homogeneous during and following mixing and spreading. Do not allow excess water or emulsion or segregation of the emulsion and aggregate fines from the coarser aggregate.

SECTION 430 – COLD IN-PLACE RECYCLED (CIR) PAVEMENT
430.03 Construction Requirements.
6. Finishing. If segregation occurs in the windrow or behind the paver, the Contractor may be required to make changes in the equipment or operations. These changes may include the following:

a. Increasing the crushing effort.
b. Adjusting the amount of water in the mixture.
c. Adjusting or modifying the paver.

The Engineer will accept cold recycled pavement visually after compaction. Correct mixture not acceptably mixed or that ravels. Reprocess areas showing an excess or deficiency of EARA or not acceptably mixed. If raveling occurs, provide additional rolling. If the Engineer determines the unacceptable material is due to the Contractor's operations, perform the corrective work at no additional cost to the Department.

430.04 Method of Measurement. The Engineer will measure acceptably completed work as follows:
1. CIR pavement will be by the square yard. No separate payment will be made for dust control or changes in equipment or operation due to segregation.

720.07 Recycled Asphalt Pavement (RAP).
4. RAP Stockpiles and Record Keeping. Place RAP stockpiles on a base with adequate drainage and construct in layers to minimize RAP segregation and ensure a workable face. Construct separate stockpiles for each source of RAP based on the category of RAP, the quality of

aggregate, type and quantity of asphalt binder, and size of processed material. Identify RAP stockpiles on a map of the stockpile areas and place signs in or near each stockpile.

Illinois

SECTION 406. HOT-MIX ASPHALT BINDER AND SURFACE COURSE
406.06 Placing. The HMA shall be placed according to the following.
(e) Spreading and Finishing.
The operating speed of the paver shall not exceed that speed which is necessary to produce a uniformly spread and struck off mat having a smooth texture without tearing or segregation.

(f) Segregation Control. Paving operations shall be conducted in a manner to prevent medium or high segregation.
Plant operations, hauling of the mix, paver operations, and the compacted mat shall be continually monitored for segregation.
The in-place HMA shall be evaluated daily for segregation according to the QC/QA document "Segregation Control of Hot-Mix Asphalt".
The Contractor's Annual Quality Control Plan or Addendum shall identify the individual(s) responsible for performing and documenting the daily evaluations. Quality Control Plans and Addendums for subsequent projects shall reflect the corrective actions taken, whether the corrective action was initiated by the Contractor or the Engineer.
ASPHALT AND BITUMINOUS ITEMS
SECTION 1030. HOT-MIX ASPHALT
1030.05 Quality Control/Quality Assurance (QC/QA).
(a) QC/QA Documents. QC/QA documents shall be as follows.
(15) Segregation Control of Hot-Mix Asphalt

Section 1102. Hot-Mix Asphalt Equipment
1102.03 Spreading and Finishing Machine.
The paver shall be equipped with a receiving hopper having sufficient capacity for a uniform spreading operation. The hopper shall be equipped with a distribution system to uniformly place a non-segregated mixture in front of the screed. The distribution system shall have chain curtains, deflector plates, and/or other devices designed and built by the paver manufacturer to prevent segregation during distribution of the mixture from the hopper to the paver screed. The Contractor shall submit a written certification that the devices recommended by the paver manufacturer to prevent segregation have been installed and are operational. Prior to paving, the Contractor, in the presence of the Engineer, shall visually inspect paver parts specifically identified by the manufacturer's check list for excessive wear and the need for replacement. The Contractor shall supply the completed check list to the Engineer noting the condition of the parts. Worn parts shall be replaced. The Engineer may require an additional inspection prior to placement of the surface course or at other times throughout the work.

Q12 response: Although not often used to identify segregation, an after-the-fact investigative field permeability test can help identify difference in compaction levels of adjacent areas of the pavement. The link for the procedure is found in Appendix B.25 in the Manual of Test Procedures is given below. __ https://idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Materials/Manual%20of%20Test%20Procedures%20for%20Materials%202020.pdf

Illinois Modified Procedure for Field Permeability Testing of Asphalt Pavements (from NCAT Report No. 99-1, Permeability of Superpave Mixtures – Evaluation of Field Permeameters by J. Allen Cooley, Jr.) Appendix B.25

Effective: January 1, 2016

1. Scope

1.1. This test method covers the in-place estimation of the water permeability of a compacted hot mix asphalt (HMA) pavement. The estimate provides an indication of water permeability of a pavement location as compared to those of other pavement locations.

1.2. The values stated in metric (SI) units are regarded as standard. Values given in parenthesis are for information and reference purposes only.

1.3. This standard does not purport to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Summary of Test Method

2.1. A falling head permeability test is used to estimate the rate at which water flows into a compacted HMA pavement. Water from a graduated standpipe is allowed to flow into a compacted HMA pavement and the interval of time taken to reach a known change in head loss is recorded. The coefficient of permeability of a compacted HMA pavement is then estimated based on Darcy's Law.

3. Significance and Use

3.1. This test method provides a means of estimating water permeability of compacted HMA pavements. The estimation of water permeability is based upon assumptions that the sample thickness is equal to the immediately underlying HMA pavement course thickness; the area of the tested sample is equal to the area of the permeameter from which water is allowed to penetrate the HMA pavement; one-dimensional flow; and laminar flow of the water. It is assumed that Darcy's law is valid.

4. Apparatus

4.1. *Hand Broom* – A broom of sufficient stiffness to sweep a test location free of debris.

4.2. *Timing Device* – A stopwatch or other timing device graduated in divisions of at least 0.1 seconds.

4.3. *Sealant* – A silicone-rubber caulk to seal the permeameter to the pavement surface.

4.4. *Field Permeameter* – A field permeameter made to the determined dimensions and specifications.

5. Preparation of Pavement Surface

5.1. Prior to conducting the test, a broom should be used to remove all debris from the pavement surface. Debris left on the pavement surface can hinder the sealing of the permeameter to the pavement surface.

6. Test Procedure

6.1. Permeameter Setup

6.1.1. Ensure that both sides of the square rubber base and the bottom of the square plastic base plate of the permeameter are free of debris.

6.1.2. Apply sealant to one side of the square, rubber base.

6.1.3. Place the side of the square, rubber base containing the sealant onto the pavement surface. Evenly apply light hand pressure to the top of the square, rubber base to force the sealant into the surface voids.

6.1.4. Place the middle, medium sized standpipe and stopper into the bottom, large standpipe of the permeameter base and seat securely in the top of the large standpipe.

6.1.5. Place the base of the permeameter onto the square, rubber base ensuring that the hole within the square, plastic base plate of the permeameter lines up with the hole in the square, rubber base.

6.1.6. Carefully place the weight over the standpipes onto the square, plastic base plate of the permeameter.

6.2. Test

6.2.1. To start the test, pour water into the medium standpipe until the water level is well above the initial head (top marked line).

6.2.2. Notice how quickly the water level drops. When the water level is at the desired initial head, start the timing device. (See Note 1) Stop the timing device when the water level within the standpipe reaches the desired final head (bottom marked line) (See Note 2). Record the time interval between the initial and final head (top and bottom marked lines).

Note 1: For relatively impermeable pavements, the water level will drop very slowly within the top tier standpipe. Therefore, the initial head should be taken within the top tier standpipe. For pavements of "medium" permeability, the water level will drop quickly through the top tier standpipe. Therefore, the initial head should be taken within the middle tier standpipe. For very permeable pavements the water level will drop very quickly through the top and middle tier standpipes but slow down when it reaches the bottom tier standpipe. Therefore, the initial head should be taken in the bottom tier standpipe.

Note 2: The initial and final head determinations should be made within the same standpipe tier.

Note 3: At some point, after several layers of silicone caulk have been allowed to build up on the square rubber base, removing the layers of silicone will be necessary. This is best done after the silicone has been allowed to "set up" somewhat but before the silicone layer becomes permanently attached to the square rubber base. This is normally around six layers.

7. Calculation

7.1. The coefficient of permeability, k, is estimated using the following equation:

$$k = \frac{aL}{At} \ln \left(\frac{h_1}{h_2}\right)$$

Where:

k = coefficient of permeability, cm/sec
a = inside cross-sectioned area of standpipe used for that test, cm^2
L = thickness of underlying HMA course, cm
A = cross-sectioned area of pavement through which water can penetrate, cm^2 (generally the same area as the bottom tier standpipe and area of hole in the square rubber base)
t = elapsed time between h_1 and h_2
h_1 = initial head in the pavement location, cm
h_2 = final head on the pavement location, cm

7.2. Report the results for k to the nearest tenth of a unit x 10^{-5} cm/sec.

p. B.123-B.125

Q15 response: The in-place HMA shall be evaluated daily for segregation according to the QC/QC document "Segregation Control of Hot-Mix Asphalt" in Appendix B.20 of the Manual of Test Procedures (link given above in Q12) It is important to understand the causes of segregation in HMA and to prevent segregation from occurring as much as possible so that a remedy is generally not needed. Segregation can occur from improper aggregate stockpile formation as well as when surge silos with HMA. Haul trucks need to be loaded correctly from the silo to prevent/reduce segregation in the trucks. Temperature segregation can occur in the trucks during long hauls, especially if the truck is not sufficiently insulated or tarped. Segregation can result from improper design of MTD and paver hopper inserts and from excessively emptying the amount of mix in the hopper between trucks. The distribution system in front of the paver screed shall have chain curtains, deflector plates, and/or other devices designed and built by the paver manufacturer to prevent segregation during distribution of the mixture from the hopper to the paver screed. The Contractor shall submit a written certification that the devices recommended by the paver manufacturer to prevent segregation have been installed and are operational. Prior to paving, the Contractor, in the presence of the Engineer, shall visually inspect paver parts specifically identified by the manufacturer's check list for excessive wear and the need for replacement. The Contractor shall supply the completed check list to the Engineer noting the condition of the parts. Worn parts shall be replaced. The Engineer may require additional inspection prior to placement of the surface course or at other times throughout the work. The Contractor's Annual Quality Control Plan or Addendum shall identify the individual(s) responsible for performing and documenting the daily evaluations. Quality Control Plans and Addendums for subsequent projects shall reflect the corrective actions taken, whether the corrective action was initiated by the Contractor or the Engineer.________If segregation of a sufficient degree is encountered during paving the Contractor will be required to correct the cause. Dialogue should occur between the Contractor and the Engineer. If the cause cannot be determined or corrected, the paving operation can be shut down by the Engineer until the problem has been remedied.

From Illinois DOT Manual of Test Procedures for Materials
https://idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Materials/Manual%20of%20Test%20Procedures%20for%20Materials%20December%202018.pdf

QC/QA Document
Segregation Control of Hot-Mix Asphalt
Appendix B.20
Effective: May 1, 2007

1.0 SCOPE

1.1 This work shall consist of the visual identification and corrective action to prevent and/or correct segregation of hot-mix asphalt.

2.0 DEFINITIONS

2.1 Segregation. Areas of non-uniform distribution of coarse and fine aggregate particles in a hot-mix asphalt pavement.

2.2 End-of-Load Segregation. A systematic form of segregation typically identified by chevron-shaped segregated areas at either side of a lane of pavement, corresponding with the beginning and end of truck loads.

2.3 Longitudinal Segregation. A linear pattern of segregation that usually corresponds to a specific area of the paver.

2.4 Severity of Segregation.

2.4.1 Low. A pattern of segregation where the mastic is in place between the aggregate particles; however, there is slightly more coarse aggregate in comparison with the surrounding acceptable mat.

2.4.2 Medium. A pattern of segregation that has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which exhibits some lack of mastic.

2.4.3 High. A pattern of segregation what has significantly more coarse aggregate in comparison with the surrounding acceptable mat and which contains little mastic.

3.0 PROCEDURE

3.1 When medium or high segregation of the mixture is identified by the Contractor, the Engineer, or the daily evaluation, the following specific corrective actions shall be taken as soon as possible. The corrective actions shall be reported to the Engineer before the next day's paving proceeds.

3.1.1 End of Load Segregation. When medium or high end of load segregation is identified, the following actions as a minimum shall be taken.

3.1.1.1 Trucks transporting the mixture shall be loaded in multiple dumps. The first against the front wall of the truck bed and the second against the tailgate in a manner which prevents the coarse aggregate from migrating to those locations.

3.1.1.2 The paver shall be operated so the hopper is never below 30 percent capacity between truck exchanges.

3.1.1.3 The “Head of Material” in the auger area shall be controlled to keep a constant level, with a 1 inch +25 mm tolerance.

3.1.2 Longitudinal Segregation. When medium or high longitudinal segregation is identified, the Contractor shall make the necessary adjustment to the slats, augers or screeds to eliminate the segregation.

3.2 When the corrective actions initiated by the Contractor are insufficient in controlling medium or high segregation, the Contractor and Engineer will investigate to determine the cause of the segregation. When an investigation indicates additional corrective action is warranted, the Contractor shall implement operational changes necessary to correct the segregation problems. Any verification testing necessary for the investigation will be performed by the Department according to the applicable project test procedures and specification limits.

3.3 The District Construction Engineer will represent the Department in any dispute regarding the application of this procedure.

Pages B.99-B.100

PFP and QCP Hot Mix Asphalt Random Jobsite Sampling
Appendix E.4
Effective: April 1, 2008
Revised: October 1, 2017

5. Sample Site Repair
   a) HMA from the paver auger system shall be used to fill the voids left in the pavement from sampling. To reduce segregation and low density in the finished mat, buckets shall be used to fill the voids left by the samples.
      1) HMA from the augers system shall be placed in clean metal buckets just prior to sampling the pavement.
      2) The metal buckets shall be filled with approximately 25% more HMA than will be removed from the void.
   b) The bucket shall be dumped directly over the void.
   c) The HMA shall be slightly leveled to provide a gradual hump over the filled void to allow compression of the mix by the roller.
   d) Unacceptable site repair shall be removed and replaced at the Contractors expense.

p. E.28-E.29

Indiana

Q15 response: Segregated, flushed, or bleeding HMA mixtures will be referred to the Department’s Division of Materials and Tests for adjudication as a failed material in accordance with 105.03.

105.03 Conformance with Plans and Specifications

All work performed, and all materials furnished shall be in reasonably close conformance with the lines, grades, cross sections, dimensions, and material requirements, including tolerances, shown on the plans or indicated in the specifications. Any deviation from the plans or specifications that may be required by the exigencies of construction will be determined by the Engineer and authorized in writing.

Plan dimensions and contract specifications values are to be considered as the target value to be strived for and complied with as the design value from which any deviations are allowed. It is the intent of the specifications that the materials and workmanship shall be uniform in character and shall conform as nearly as realistically possible to the prescribed target value or to the middle portion of the tolerance range. The purpose of the tolerance range is to accommodate occasional minor variations from the median zone that are unavoidable for practical reasons. When a maximum or minimum value is specified, the production and processing of the material and the performance of the work shall not be preponderantly of borderline quality or dimension.

When construction equipment, office equipment, production equipment, or testing equipment are specified in metric sizes, any such equipment that has been built to nearly equivalent English system dimensions will be accepted. When such equipment is specified in English system sizes, any such equipment that has been built to nearly equivalent metric sizes will be accepted.

If the Engineer finds the materials or the finished product in which the materials are used are not within reasonably close conformance with the plans and specifications but that reasonably acceptable work has been produced, the Engineer will determine if the work will be accepted and remain in place. In this event, the basis of acceptance will be documented by contract modification which will provide for an appropriate adjustment in the contract price for such work or materials as deemed necessary to conform to the determination based on engineering judgment.

If the Engineer finds the materials or the finished product in which the materials are used or the work performed are not in reasonably close conformance with the plans and specifications and have resulted in an inferior or unsatisfactory product, the work or materials shall be removed and replaced or otherwise corrected with no additional payment

DIVISION 400 – ASPHALT PAVEMENTS
SECTION 401 – QC/QA HMA PAVEMENT
CONSTRUCTION REQUIREMENTS
401.10 General
The paver shall be equipped with means of preventing the segregation of the coarse aggregate particles when moving the mixture from the paver hopper to the paver augers. The means and methods used shall be in accordance with the paver manufacturer's instructions and may consist of chain curtains, deflector plates, or other such devices, or any combination of these.
Segregation or flushing or bleeding of HMA mixtures will not be allowed. Corrective action shall be taken to prevent continuation of these conditions. Segregated or flushed or bleeding HMA mixtures shall be removed if directed. All areas showing an excess or deficiency of binder shall be removed and replaced.

SECTION 402 – HMA PAVEMENT
CONSTRUCTION REQUIREMENTS
402.10 General
Segregation, flushing or bleeding of HMA mixtures will not be allowed. Corrective action shall be taken to prevent continuation of these conditions. Areas of segregation, flushing or bleeding shall be corrected, if directed. All areas showing an excess or deficiency of asphalt materials shall be removed and replaced.

SECTION 409 – EQUIPMENT
409.02 Mixing Plant
(b) CMA Mixing Plant
The mixing plant shall be of sufficient capacity and coordination to adequately handle the proposed CMA construction. The mixing unit shall be a twin shaft pugmill or other approved mixer, including the drum type capable of producing a consistent uniform mixture. The outlet of the mixer shall be such that it prevents segregation of the material when discharged.

SECTION 410 – QC/QA HMA – SMA PAVEMENT
CONSTRUCTION REQUIREMENTS
Segregation, flushing or bleeding of SMA mixtures will not be allowed. Corrective action shall be taken to prevent continuation of these conditions. Segregated, flushed or bleeding of SMA mixtures shall be removed if directed. All areas showing an excess or deficiency of binder shall be removed and replaced.

SECTION 416 - COLD IN-PLACE RECYCLING, CIR

(f) Cold In-Place Recycler Equipment

In either case, the screed shall be controlled by electronic grade and cross slope control. The equipment shall be of sufficient size and power to spread the recycled material in one continuous pass, without segregation, in accordance with 105.03. Heating of the screed will not be allowed.

Q21 response: https://www.in.gov/dot/div/contracts/standards/GIFE/GIFEMaster.pdf page 13-13

GIFE HOT MIX ASPHALT, HMA, PAVEMENT

Rev. 12-16-20

13.15 SEGREGATION/FLUSHING *(Rev. 09-29-09)*
After completion of the rolling portion of the paving operation, look for defects in the newly placed mat. Segregation and flushing are two common problems. Segregation occurs when the fine and coarse aggregates become separated from each other during the hauling or paving operation. Segregated mats feature locations where there are primarily coarse aggregate particles with no fines—the appearance is similar to an open graded mixture. There will be other locations within a segregated mat where there are few, if any, pieces of coarse aggregate and mainly consists of asphalt coated fines—appearing like a sand surface. Common causes of segregation include improper loading into trucks, faulty paver auger operation, and situations where a paver is forced to stop because the hopper runs out of mixture. In order to avoid this situation, many paving trains include a material transfer device sometimes referred to as an MTD or a shuttle buggy. Shuttle buggies essentially provide a larger hopper for the paver and permit the paving operation to proceed almost indefinitely down the road as long as a sufficient number of trucks hauling mixture are available.

Flushed pavements have locations where liquid asphalt collects on the surface of the mat. This may result from excess tack coat being brought up through the mat, improper mixing of the mixture, or too much PG binder in the mixture.

The remedy for segregated mats usually requires removal of the affected areas and replacement with suitable material. Minor areas of segregation can be repaired by using a sand seal coat. Flushed pavement areas may require removal and replacement or diamond grinding or other fine milling to remove the excess asphalt. Mark all segregated or flushed areas for correction by the contractor prior to being covered up by another lift of material or opened to traffic. Corrective action should be in accordance with the contractor's QCP. If the QCP does not address the repair of segregated or flushed pavements and an agreement on a solution cannot be reached with the contractor, contact the AE. The Division of Materials and Tests, Division of Construction Management and Office of Pavement Engineering are all available resources for determining the scope of the required repair.

Another common defect in a newly placed mat is pulling or tearing. The mat can be torn or pulled by a paver that is traveling too fast, a paver with a screed that is worn or not heated properly, compacted by a roller that is traveling too fast or rolling a mix that is too tender. Mark all torn areas when discovered so they can be repaired prior to placing another mixture on top or opening the road to traffic. All torn areas must be repaired in accordance with the QCP. If the QCP does not address the repair of tears in the mat, contact the AE if no agreement on an appropriate repair can be reached with the contractor.

Iowa

Not linked in FHWA page.
https://iowadot.gov/specifications/
in electronic reference library (ERL): https://iowadot.gov/erl/

https://iowadot.gov/erl/current/GS/content/2001.htm
Section 2001. General Equipment Requirements
2001.08 EQUIPMENT FOR PREWETTING AGGREGATES AND AGGREGATE MIXTURES.
Use equipment complying with one of the following:

B. Pugmill Mixer.

2. If using continuous flow type mixers, use ones that:

- Have twin mixing shafts, and
- Are equipped with a hopper or bin at the discharge end of the mixer designed to minimize segregation of the mixed materials.

2001.13 SPREADERS.
This article applies to equipment used for distribution of certain materials, other than liquids, where it is required that the material be distributed on a roadbed at a specified uniform rate.

B. Self-Propelled Cover Aggregate Spreaders.
Comply with the requirements of Article 2001.13, A, and the following:

5. Provide a hopper with the following qualifications (conveyers are suitable for conveying the aggregate from the hopper to the spreading element):

d. Augers or agitators distribute aggregate uniformly to the spreading element without segregating aggregate particles.

2001.22 PLANT EQUIPMENT FOR HOT MIX ASPHALT MIXTURES.
K. Mixer.
2. Continuous Mixer.
d. Regulate the distance to the receiving vehicle to minimize segregation.

L. Hot Mixture Storage.

2. Use hot mixture storage bins that are either 1) surge bins to balance production capacity with hauling and placing capacity; or 2) storage bins which are heated and/or insulated and have a controlled atmosphere around the mixture. Use hot mixture storage bins that:

d. Do not result in significant segregation, damage, or cooling.

Section 2203. Hot Mix Asphalt Base

2203.01 DESCRIPTION.
Construct an HMA base, as specified, upon a prepared or corrected subgrade or a previously constructed base or subbase.

2203.02 MATERIALS.
Apply Article 2303.02.

2203.03 CONSTRUCTION.
Construct HMA base to the dimensions shown in the contract documents and according to Section 2303.

2203.04 METHOD OF MEASUREMENT.
Measurement for the various items involved in the construction of a HMA base will be according to Article 2303.04.

2203.05 BASIS OF PAYMENT.
Payment for the various items involved in the construction of a HMA base will be as provided in Article 2303.05.

Section 2303. Flexible Pavement
2303.03 CONSTRUCTION.
C. Construction.

3. Handling, Production, and Delivery.
Ensure plant operation complies with the following requirements:

d. Production of Hot Mix Asphalt Mixtures.

3) Minimize segregation to the extent that it cannot be visibly observed in the compacted surface.

4. Placement.

i. After spreading, carefully smooth to remove all segregated aggregate and marks.

Section 2318. Cold In-Place Recycled Asphalt Pavement
2318.03 CONSTRUCTION.
E. Placement of the Recycled Material.

1. Deposit CIR mixture in a windrow, into a spreader or paver (as required by Article 2318.03, A)), or load into trucks, without segregation.

2. Place and finish CIR mixture in one continuous pass, without segregation. Ensure the surface of the CIR lift has a uniform cross-slope as specified in the contract documents. Ensure lift thickness is a minimum of 2 inches. If using a pick-up machine to feed the windrow into the paver hopper, ensure it is capable of picking up the entire windrow to the underlying material.

https://iowadot.gov/erl/current/CM/content/CM%202.50.htm

2.50 CONTRACTOR PAYMENTS AND PRICE ADJUSTMENTS

2.53 PRICE ADJUSTMENT GUIDE FOR REASONABLY CLOSE CONFORMING, REASONABLY ACCEPTABLE, AND DEFICIENT WORK

G. Asphalt

4. Segregation in Asphalt Pavement
When mixture segregation occurs in the pavement such that the composition and quality of the mixture required by specification are not uniformly attained, the sections judged deficient may be required to be removed and replaced as defective work. An adjustment in contract price may be made for deficient work for the cases described in the following schedule.

a. Pavement Surface

The adjustments in contract price are to be applied to the entire paver lane width and lift thickness between extreme areas of segregation. Price adjustment shall apply only to the payment for the asphalt mixture. Price adjustments are defined in *Appendix 2-34(K)*.

ADJUSTMENT SCHEDULE

Case I (Payment is 80% of contract unit price.)
When uniform surface texture and mixture composition is evident (by visual observation) except for occasional and random areas of segregation, the mix shall be subject to price adjustment if the area determined segregated equals or exceeds one square yard per station per paver width (length determined by longitudinal distance both directions from segregated area).

Case II (Payment is 50% of contract unit price.)
When a nonuniform surface texture and mixture composition is evident (by visual observation) and there is a regular interval of numerous areas of segregation connected or nearly connected with longitudinal traces of segregation, the mix shall be subject to price adjustment if the total area segregated equals or exceeds 3 square yards per station per paver lane width (length determined by longitudinal distance both directions from the extreme ends of areas of segregation).

Case III Longitudinal Streaks (Payment is 80% of contract unit price.)
When a nonuniform surface texture and mixture composition is evident (by visual observation) and in the form of longitudinal streaks of 3 inches or more in width, the mix shall be subject to price adjustment if the segregation occurs at a rate that exceeds one square yard per station. The rate is determined by multiplying approximate width by length of the streaks to determine area and dividing by the length of the streaks (in stations). Longitudinal streaks most commonly occur with the windrow-pickup process, particularly when resurfacing superelevated curves. Streaks are typically seen in the wheelpath areas and occasionally in the center of the lane. Streak widths typically vary from 3 to 12 inches and may be continuous or intermittent. This type of segregation results in longitudinal cracking.

More severe surface and mixture segregation may require corrective procedures as:

- full width thin layer one inch thick resurfacing or
- removal of asphalt mixture course with no extra payment and replacement with construction that fully complies

Note: Determination of segregation in asphalt pavement is by visual examination in accordance with current specifications. The engineer may consider further verification through coring and extraction tests. Segregation case examples, with corresponding price adjustment calculations, are illustrated in *Appendix 2-34(K)*.

b. Fillets & Runouts

This price adjustment procedure does not apply to fillets, bridge runouts, or other hand-worked areas outside of the normal paver lane width.

c. Base & Intermediate Courses
The price adjustment percentages shall be reduced as indicated in *Appendix 2-34(K)*for all base or intermediate courses, except when such mixture is specified and used as the surface course.

d. Procedure for Determination of Price Adjusted Quantities
The segregation case examples shown in *Appendix 2-34(K)* illustrate a concept that may be used to define the severity of segregation and appropriate price adjustment factor. It is not required, however, to physically measure each area of segregation to determine a quantity of asphalt mixture that is subject to price adjustment. The intent is to define the quantity subject to price adjustment by identifying the number of truckloads in which segregated areas are evident. This obviously takes some judgment to decide how large or severe an area must be before it is price adjusted. The one square yard area shown in examples is a "rule-of-thumb." Most importantly, segregated areas that exhibit an obvious concentration of coarse aggregate resulting in a nonuniform open texture should be price adjusted.

Whenever segregation is observed, the contractor shall be advised immediately and the inspector must document the deficiency with a Noncompliance Notice. The notice should reference the applicable specification and indicate the project engineer will review the work to determine the acceptability of the work. It is recommended that a Noncompliance Notice be issued when segregation is initially observed with final evaluation and price adjustment determined later but prior to project acceptance.

Timeliness is important for two reasons. First, the contractor must take corrective action immediately. Failure to do so should result in suspension of work. Secondly, early identification of unacceptable work allows for resolution of any disputes before there is an "implied" acceptance. *Construction Manual 1.12* discusses the enhancement of working relationships by timely notification of unacceptable work.

For streak type segregation, it will be necessary to identify and tabulate the location and length of the segregated streak areas subject to price adjustment and base the price adjustment on the mix quantity within the beginning and ending station limits of the streaks.

Normally this procedure should be repeated for each day from header to header on the day following placement. Each day's run can be tabulated showing a summary of affected tons of asphalt mixture subject to price adjustment.

https://iowadot.gov/erl/current/CM/content/Appendix%202-34(K).pdf

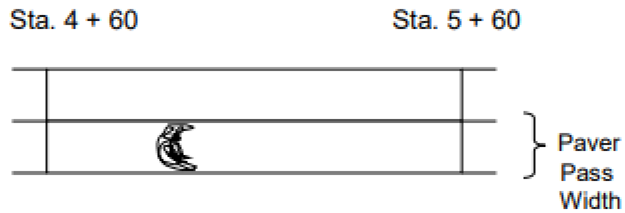
TABLE K

Price Adjustment for Segregation Examples

TABLE K

Price Adjustment for Segregation Examples

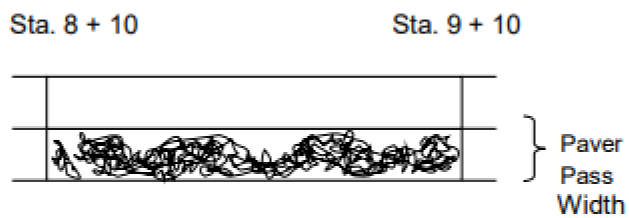
Case I Visual Segregation – 1 sq. yd. or more / station



Surface Course
Mix Price Adjustment: 20%

Base & Intermediate Course
Mix Price Adjustment: 5%

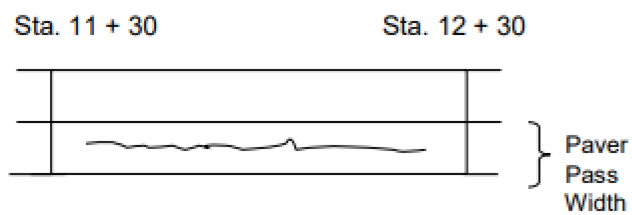
Case II Visual Segregation – 3 sq. yd. or more (total) / station



Surface Course
Mix Price Adjustment: 50%

Base & Intermediate Course
Mix Price Adjustment: 5%

Case III Visual Segregation (Longitudinal Streaks) – 1 sq. yd. or more / station



Surface Course
Mix Price Adjustment: 20%

Base & Intermediate Course
Mix Price Adjustment: 5%

<u>Application of Price Adjustment</u>

The price adjustment applies to the entire area defined by the length times the paving width where this condition exists. For example, if a **Case I** condition exists for a Surface Course, which was paved for a length of 20 stations, paver width at 12 ft., paving depth of 2 inches, and the unit price for HMA Surface mix at $20.00 per ton:

Price Adjustment = (**20%**)(1/100)(**20 stations**)(100 ft./1 station)(**2 in.**)(1 ft./12 in.)(**12 ft.**)
(145 lbs./cu. ft.)(1ton/2000 lbs.)(**$20.00/ton**)

= **<u>$1160.00</u>**

<u>Application of Price Adjustment</u>

The price adjustment applies to the entire area defined by the length times the paving width where this condition exists. For example, if a **Case I** condition exists for a Surface Course, which was paved for a length of 20 stations, paver width of 12 ft., paving depth of 2 inches, and the unit price for HMA Surface mis at $20.00 per ton:

Price Adjustment = (**20%**)(1/100)(**20 stations**)(100 ft./1 station)(**2 in.**)/(1ft./12 in.)(**12 ft**.) (145 lbs./cu. ft.)(1 ton/2000lbs.)(**$20.00/ton**)
= **$1160.00**

Construction Manual - Chapter 8

Hot Mix Asphalt (HMA) Pavement, Bases and Subbase

https://iowadot.gov/erl/current/CM/content/CM%208.50.htm

8.55 COLD WEATHER ASPHALT CONSTRUCTION

The specifications contain limitations for placement of asphalt mixture and liquid bitumen under cold weather conditions. These restrictions apply to pavement surface temperature and time of year, and vary according to whether layer is surface course, lower intermediate, or base course, and nominal lift thickness.

Cold weather construction problems may show up in the form of mat raveling, low density, high voids, segregation, slippage, or failure of tack coat to break. Project engineer and inspector should be aware of other weather-related conditions which may further limit placement.

https://iowadot.gov/erl/current/CM/content/CM%208.70.htm

8.70 INSPECTOR'S GUIDE - ASPHALT PAVING & RESURFACING

Is surface texture uniform, dense, and free from irregularities, tearing, pneumatic and/or steel roller marks, check cracks, solvent spots, and segregation (*Specifications 2303.03, C, 4, and 2303.03, C, 5*, and *Construction Manual 2.53*)?

https://iowadot.gov/erl/current/CM/content/CM%208.80.htm

8.80 USE OF SPECIAL EQUIPMENT

Material Transfer Vehicles

Material transfer vehicles (MTVs) provide mix surge capacity, which allows more constant paver speed and more efficient paving operation. These vehicles operate in front of or beside the paver and receive loads of asphalt mix from delivery trucks. They perform as a mobile 22 – 33 tons asphalt mix surge bin that re-mixes and continually feeds mix to the paver hopper. Use of these vehicles results in smoother pavement by minimizing paver stops and eliminating trucks bumping into the paver. More uniform surface texture and pavement density is also achieved, as mixture and temperature segregation are virtually eliminated by MTV's remixing capabilities. Two common MTV models used in Iowa are Roadtec SB-2500 "Shuttle Buggy" and Weiler E2850 "Remixing Transfer Vehicle".

Mat Smoothness Machine

Several contractors have used Terex (Cedarapids) MS-3 or MS-4 Mat Smoothness Machines on paving and resurfacing projects. This is an asphalt material receiving hopper and elevator that deposits asphalt mix into the paver hopper. Use of this equipment allows for a more consistent paver operation by providing some surge capacity for paver, only on a much smaller scale than MTVs. In some cases, it can also help re-mix material and minimize segregation.

It weighs approximately 18,800 pounds empty and has a hopper capacity of 2.22 cubic yards. Weight restrictions are not a concern with this piece of equipment.

When using Mat Smoothness Machines (or MTVs), the paver hopper should be kept relatively full at all times. If the hopper is allowed to draw down too far, coarse aggregate collected in the sides and corners of the paver hopper might be drawn down and create streaks of segregation in the mat surface.

Windrow Pick-Up Equipment
Many Iowa contractors are equipped to construct asphalt resurfacing and paving projects using windrow pick-up equipment. This process is allowed by specification.

With this process, asphalt mix is deposited in a windrow onto the pavement surface using bottom dump trailers. A windrow pick-up elevator deposits the material into the paver hopper. Again, the primary advantages are contractor efficiency, uniform speed of operation, and elimination of delivery trucks bumping into the paver.

Segregation has occurred on several projects on which this equipment was used. Truckload and longitudinal strip type segregation are potential problems. The contractor should balance their asphalt mix delivery with the mat placement rate to keep the paver hopper at a nearly uniform level, which helps avoid segregation. Balancing delivery and placement also minimize the need to either feed the hopper additional mix or remove excess windrow material with a mini-loader. The windrow should be placed to feed the center of the windrow pick-up machine. A windrow that is improperly located can place an eccentric force on the pick-up machine, which can force the paver to lose proper centerline alignment. It is also important for the contractor to pick up all windrow material from the pavement surface, and not allow the windrow to extend more than two truckloads in front of the paver to avoid excessive cooling of the mix.

Normal asphalt mix laydown temperature limitations apply to this process.

It has been shown that this process can be used successfully for the lower lift of a full depth pavement; however, it is important to make sure the pick-up machine does not disturb (pick up) the subgrade or subbase material.

If streak type segregation is suspected, a trench can be sawed transversely across the lane and the profile viewed for voids and/or a non-uniform aggregate matrix. Cores can also be cut to ascertain if segregation is present. If segregation is determined to exist, costs of the coring or sawing will be at the contractor's expense.

Duty	Frequency	Specification / Resource	Commentary
Prior to Asphalt Mixture Placement			
Check / Observe loading of asphalt mixture haul trucks at plant	Periodically	Specification 2303.03, C, 3, d	Check for signs of overheated mix (blue smoke). Check for clumps of cold mix remaining from previous load. Check mixing time and mix appearance for proper coating of aggregate. Check for proper and uniform mix temperature. Check that multiple drops of mix from the silo are used to minimize segregation (roll-down) of mix in trucks.
Check asphalt mixture placement operation (general)	Periodically	Specification 2303.03, C, 3, d Specification 2303.03, C, 4	Asphalt mixtures should be supplied to the paver in a uniform and continuous manner, resulting in a minimal number of paver stoppages. Asphalt mixture placement operation shall produce a mat with uniform temperature and composition, minimizing segregation to the extent that it is not visibly observed in the compacted surface.
Check / Observe unloading of truck into paver hopper	Periodically	Specification 2303.03, C, 3, d	Check for signs of overheated mix (blue smoke). Check for clumps of cold mix remaining from previous loads. Ensure proper dumping procedures used to keep mix flowing as a mass, to minimize coarse aggregate roll-down (segregation).
Check / Observe proper placement of mix into windrow	Periodically	Specification 2303.03, C, 3, d	Check that windrow is centered in lane to be placed. Check for uniformity of windrow size & shape. Check for excessive mix drop heights, leading to coarse aggregate segregation at base of windrow. Check for clumps of cold mix near end of loads. Ensure that haul trucks are not allowed to drive over (compact) existing windrow.
Check for uniform material flow through paver	Periodically	Specification 2303.03, C, 3, d	Restrictions to uniform flow of mix will result in segregation. Non-uniform head of material at the screed will result in waves in the mat, as well as variations in density. Check for uniform head of material in the paver hopper (typically 25 to 75% full), through the flow gates, along length of augers, and ahead of the screed.

Check / Observe HMA compaction (roller) operation	Periodically	Specification 2303.03, C, 5	Check for proper equipment and procedures. Check for consistent mat temperature & rolling pattern (with special attention to Class II compaction areas); Check surface for roller marks, mix pick-up, waves in mat, and possible segregation.
Check longitudinal joints	Periodically	Specification 2303.03, C, 6	Check for proper overlap (typically 1" within 1/2" tolerance) and procedures used for longitudinal joint construction. Pavement edges should be carefully aligned and loose lift thickness set to result in well-matched centerline joint. Check for adequate mix at end of screed to reduce potential for segregation and mismatched joint.
After Asphalt Mixture Placement			
Check completed pavement section visually for uniformity	Daily, or as needed	Construction Manual 2.53 Form 830245 Construction Manual App. 2-34(K)	Daily visual examination of mat surface is recommended to detect mix segregation as soon as possible, allowing timely changes in equipment or procedures to be made in order to minimize future occurrences. If segregation is suspected, the inspector should inform his supervisor and the contractor. A Noncompliance Notice (Form 830245) and subsequent price adjustment may follow, if warranted.

Kansas

602 - HOT MIX ASPHALT (HMA) CONSTRUCTION (Quality Control/Quality Assurance (QC/QA))

602.4 CONSTRUCTION REQUIREMENTS

a. Plant Operation. Adjust all plant operations to operate continuously.

(3) Preparation of HMA. Introduce asphalt binder into the prepared aggregate in the proportionate amount determined by the Pbr in the JMF.

(e) Wasted Material. Wasted material is not measured for pay. If after an interruption of production, the drum-mixer contains cold, uncoated or otherwise unsuitable material, waste material through a diversion chute. In a continuous or batch plant drier, waste unsuitable material through the pugmill.

At the end of a production run, waste any segregated material in the cone of the storage bin.

e. Paving Operations. Except when placing SM-4.75A, SM-9.5A or SR-9.5A asphalt mixtures, remix the material transferred from the hauling unit, prior to placement. Use equipment such as a mobile conveyor, material transfer device, shuttle buggy material transfer vehicle, material transfer paver or paver with remixer conveyor system. After starting the project with the equipment listed above, and after producing HMA pavement density within the limits specified in TABLE 602-7, the Engineer will consider other types of equipment or modifications to pavers that will produce less segregation. The use of equipment as noted above shall not relieve the Contractor of the responsibility to comply with TABLE 602-7. The Engineer will check the pavement for longitudinal streaks and other irregularities. Make every effort to prevent or correct any irregularities in the pavement, such as changing pavers or using different and additional equipment.

Do not raise (dump) the wings of the paver receiving hopper at any time during the paving operation. The Engineer may waive this requirement if it is determined that raising (dumping) the wings will not produce detrimental segregation. If segregation or irregularities in the pavement surface or density are noted, review the plant, hauling and paving operations and take corrective action. The recommendations made in KDOT's "Segregation Check Points" should reduce the segregation and irregularities to an acceptable level. Copies of KDOT's "Segregation Check Points" may be obtained from the KDOT District Office or Field Engineer.

Spread the HMA and finish to the specified crown and grade using an automatically controlled HMA paver. Operate the paver at a speed to provide a uniform rate of placement without undue interruption. At all times, keep the paver hopper sufficiently full to prevent non-uniform flow of the HMA to the augers and screed.

If the automatic grade control devices break down, the Engineer may allow the paver to operate to the close of the working day, provided the surface is satisfactory. Do not operate the paver without working automatic control devices upon another lift that was laid without automatic controls.

(1) Surface Quality. Spread the HMA without tearing the surface. Strike a finish that is smooth, free of segregation, true to cross section, uniform in density and texture and free from surface irregularities. If the pavement does not comply with all of these requirements, plant production and paving will be suspended until the deficiency is corrected.

The Engineer will check segregation and uniformity of density using methods outlined in Section 5.8.3 - Segregation Check Using the Nuclear Density Gauge, Part V. For shoulders with a plan width of less than or equal to 3 feet, and placed at the same time as the traveled way, do not take nuclear density readings on the shoulder nor within 1 foot of the shoulder unless the pavement section is uniform across the entire roadway. The acceptable criteria for density uniformity are in TABLE 602-7.

TABLE 602-7: SEGREGATION AND UNIFORMITY OF DENSITY CHECK		
Mix Designation	**Maximum Density Range (highest minus lowest)**	**Maximum Density Drop (average minus lowest)**
All	4.4 lbs./cu. ft.	2.2 lbs./cu. ft.

Whenever the results from 2 consecutive density profiles fail to comply with both of the requirements listed in TABLE 602-7, plant production and paving will be suspended. Follow the procedures listed in the Profile Evaluation Subsection of Section 5.8.3-Segregation Check Using the Nuclear Density Gauge, Part V until production may be resumed.

Joint density testing and the associated requirements listed below do not apply for HMA lift thicknesses less than or equal to 1 inch.

602.8 MIXTURE ACCEPTANCE

a. General. Test each mix designation at each plant for compliance with TABLE 602-1. Acceptance will be made on a lot by lot basis contingent upon satisfactory test results. Obtain test samples of the mix designation from the roadway behind the paving operation before compaction. The sampling device and procedures used to obtain the samples must be approved by the Engineer. Use KT-25 for obtaining HMA from the roadway and splitting of the sample. The Contractor's quality control tests will be used for acceptance provided those results are verified by KDOT.

A load or loads of mixture which, in the opinion of the Engineer, are unacceptable for reasons such as being segregated, aggregate being improperly coated, foaming aggregate or being outside the mixing temperature range may be rejected. Verification samples will be taken by the Engineer at randomly selected locations from behind the paver. Fill all sample locations before compaction.

The V_a test values will also be used to determine V_a pay adjustments according to subsection 602.9d. Va pay adjustments apply to the HMA placed on the traveled way and shoulders (including ramps and acceleration and deceleration lanes).

g. Increased Lot Size. After 8 consecutive sublots have been produced within the tolerance shown for all mix characteristics listed in TABLE 602-12 and without a Va penalty, the sublot size may be increased to 1,000 tons (lot size of 4,000 tons), provided the normal production rate of the plant is greater than 250 tons per hour. Provide immediate notification of lot size changes to the Engineer any time a change is made.

After 8 additional consecutive sublots have been produced at the 1,000 ton sublot size, the sublot size may again be increased to 1,250 tons per sublot (lot size of 5,000 tons), provided all 8 consecutive 1,000 ton sublots have been produced within the tolerances shown for all mix characteristics listed in TABLE 602-12, without a V_a penalty, production rates for the previous 2 days have been greater than 3,750 tons per day, and a minimum of 2 of the last 3 segregation profile checks comply with TABLE 602-14.

TABLE 602-14: SEGREGATION PROFILE CHECKS FOR INCREASED SUBLOT SIZE

Mix Designation	Maximum Density Range (highest minus lowest)	Maximum Density Drop (average minus lowest)
All	3.1 lbs./cu. ft.	1.9 lbs./cu. ft.

If subsequent test results fall outside the tolerances shown for any mix characteristic listed in TABLE 602- 12 or a V_a penalty is incurred, decrease the sublot size to 750 tons. If the production rates fall below 3,750 tons per day for 2 consecutive days or a minimum of 2 of the last 3 segregation profile checks fail the above requirements, then reduce the 1,250 ton sublots size to 1,000 ton per sublot provided the TABLE 602-12 criteria is met and no V_a penalty is incurred.

When the increased lot size criteria are again met for 4 consecutive sublots, the sublot may be increased as the limits given above.

614 – HMA BASE (REFLECTIVE CRACK INTERLAYER (RCI)

a. Plant Operation. Adjust all plant operations to operate continuously.

(3) Preparation of HMA. Introduce asphalt binder into the prepared aggregate in the proportionate amount determined by the P_{br} in the JMF.

(e) Wasted Material. At the end of a production run, waste any segregated material in the cone of the storage bin.

e. Paving Operations. The Engineer will check the pavement for longitudinal streaks and other irregularities. Make every effort to prevent or correct any irregularities in the pavement, such as changing pavers or using different and additional equipment.

Do not raise (dump) the wings of the paver receiving hopper at any time during the paving operation. The Engineer may waive this requirement if it is determined that raising (dumping) the wings will not produce detrimental segregation. If segregation or irregularities in the pavement surface or density are noted, review the plant, hauling and paving operations and take corrective action. The recommendations made in KDOT's "Segregation Check Points" should reduce the segregation and irregularities to an acceptable level. Copies of KDOT's "Segregation Check Points" may be obtained from the KDOT District Office or Field Engineer.

Spread the HMA and finish to the specified crown and grade using an automatically controlled HMA paver. Operate the paver at a speed to provide a uniform rate of placement without undue interruption. At all times, keep the paver hopper sufficiently full to prevent non-uniform flow of the HMA to the augers and screed.

If the automatic grade control devices break down, the Engineer may allow the paver to operate to the close of the working day, provided the surface is satisfactory.

(1) Surface Quality. Spread the HMA without tearing the surface. Strike a finish that is smooth, free of segregation, true to cross section, uniform in density and texture and free from surface irregularities. If the pavement does not comply with all of these requirements, plant production and paving will be suspended until the deficiency is corrected. The Engineer may verify segregation and uniformity of density requirements in TABLE 602-7 are met by using methods outlined in Section 5.8.3 – Segregation Check Using the Nuclear Density Gauge, Part V.

614.7 MIXTURE ACCEPTANCE

a. General.

A load or loads of mixture which, in the opinion of the Engineer, are unacceptable for reasons such as being segregated, aggregate being improperly coated, foaming aggregate or being outside the mixing temperature range may be rejected. The Engineer will take verification samples using the same sampling and splitting procedure as approved for the Contractor's quality control tests.

5.8.3. SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE
(standalone pdf)

http://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/specprov/2015/PDF/15-06001.pdf
KS Special specs

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE STANDARD SPECIFICATIONS, 2015 EDITION
Add a new SECTION to DIVISION 600:
PLANT MIX ASPHALT CONSTRUCTION (BM-MIXES)

3.0 CONSTRUCTION REQUIREMENTS

a. Plant Operation.

(4) Preparation of HMA.

(f) Wasted Material.

At the end of a production run, waste any segregated material in the cone of the storage bin.

e. Paving Operations.

(1) General. Except when placing BM-1 or BM-1A asphalt mixtures, remix the material transferred from the hauling unit, prior to placement. Use equipment such as a mobile conveyor, material transfer device, shuttle buggy material transfer vehicle, material transfer paver or paver with remixer conveyor system. After starting the project with the equipment listed above, and after producing HMA pavement density within the limits specified in TABLE 8, the Engineer will consider other types of equipment or modifications to pavers that will produce less segregation. The use of equipment as noted above shall not relieve the Contractor of the responsibility to comply with TABLE 8. The Engineer will check the pavement for longitudinal streaks and other irregularities. Make every effort to prevent or correct any irregularities in the pavement, such as changing pavers or using different and additional equipment.

Do not raise (dump) the wings of the paver receiving hopper at any time during the paving operation. The Engineer may waive this requirement if it is determined that raising (dumping) the wings will not produce detrimental segregation. If segregation or irregularities in the pavement surface or density are noted, review the plant, hauling and paving operations and take corrective action. The recommendations made in KDOT's "Segregation Check Points" should reduce the segregation and irregularities to an acceptable level. Copies of KDOT's "Segregation Check Points" may be obtained from the KDOT District Office or Field Engineer.

Spread the HMA and finish to the specified crown and grade using an automatically controlled HMA paver. Operate the paver at a speed which shall provide a uniform rate of placement without undue interruption. At all times, keep the paver hopper sufficiently full to prevent non-uniform flow of the HMA to the augers and screed.

If the automatic grade control devices break down, the Engineer may allow the paver to operate to the close of the working day, provided the surface is satisfactory. Do not operate the paver without working automatic control devices upon another lift that was laid without automatic controls.

As needed, the Engineer will obtain representative samples of the asphalt mixture from behind the laydown machine (unless approved otherwise by the Engineer), before the mixture is compacted. Use Kansas Test method KT-25 for obtaining the asphalt mixture and splitting of the sample. Repair the holes when the samples are taken behind the laydown machine.

(2) Surface Quality. Spread the HMA without tearing the surface. Strike a finish that is smooth, free of segregation, true to cross section, uniform in density and texture and free from surface irregularities. If the pavement does not comply with all of these requirements, plant production and paving will be suspended until the deficiency is corrected.

The Engineer will check segregation and uniformity of density using methods outlined in Section 5.8.3, Segregation Check Using the Nuclear Density Gauge, Part V. The acceptable criteria for density uniformity are in TABLE 8.

TABLE 8: SEGREGATION AND UNIFORMITY OF DENSITY CHECK

Mix Designation	Maximum Density Range (highest minus lowest)	Maximum Density Drop (average minus lowest)
All	4.4 lbs./cu. ft.	2.2 lbs./cu. ft.

Whenever the results from 2 consecutive density profiles fail to comply with both of the requirements listed in TABLE 8, plant production and paving will be suspended. Follow the procedures listed in the Profile Evaluation Subsection of Section 5.8.3, Segregation Check Using the Nuclear Density Gauge, Part V until production may be resumed.

4.0 PROCESS CONTROL
a. Requirements for All Mix Designations.

(2) Acceptance Tests.

The material will be tested for acceptance according to the Contract Documents. However, any load or loads of HMA which, in the opinion of the Engineer, are unacceptable for reason of being excessively segregated, aggregate improperly coated, foaming aggregate or of excessively high or low temperature will be rejected.

NOTE: "The recommendations made in KDOT's "Segregation Check Points" should reduce the segregation and irregularities to an acceptable level. Copies of KDOT's "Segregation Check Points" may be obtained from the KDOT District Office or Field Engineer."

Q12 response: Segregation check using the nuclear density gauge - http://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/Connections/ConstManual/2018/5.8.3._Segregation_Check_Nuke_Gauge.pdf

5.8.3. SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE
1. OBJECTIVE

The objective of these instructions is to give guidance on establishing a density profile behind the laydown machine. This is accomplished by taking multiple readings within a 50 foot (15 m) section. Use the nuclear density gauge results to plot a density profile. Check the profile for a drop in density caused by segregation. Check the roadway profile location for visible segregation. It is important to record the profile location to permit possible future evaluation of the segregated section. It is intended that English projects use English values and that metric projects use metric values.

2. PROJECT STARTUP

NOTE: Check gauge to verify it is in asphalt mode.
At the start of the project, allow the paving unit 1000 ft (300 m) progress with each mix designation before implementing a profile analysis.

3. SELECTION OF PROFILE LOCATIONS

It is intended that visibility identifiable segregated areas be profiled. Two basic types of segregation are encountered on the roadway. They are truck load segregation and longitudinal segregation.

- Truck load segregation (spot, chevron, or gull wing type segregation) has a visible pattern repeated with each truck load. These segregated areas are about the same longitudinal distance apart. This type of segregation will normally occur 10 to 25 ft (3 to 7.5 m) from the screed stop point when trucks dump directly into the paver. The use of a material transfer vehicle (MTV) has been known to extend this further down the paving section.

- Longitudinal segregation (streaking) is normally caused by the paver. This streaking is parallel to the centerline of the project, and may occur continually, or may periodically start and stop.

If the laydown machine continues to progress without stops, then the engineer will establish profile starting points. If the laydown machine periodically stops, then use the location where the screed stops as the "zero" point for the profile starting point. The Engineer should use caution on whether to run a profile if the laydown machine has been stopped for more that 10 minutes, due to cooling of the mix.

4. LOCATION OF DENSITY READINGS

Take readings approximately every 5 ft (1.5 m) along the longitudinal direction. The first reading should be located approximately 10 ft (3 m) behind the screed (zero point). If a segregated location is visible between two locations, then take an additional reading at that location.

- When checking for truck load segregation, the longitudinal distance from centerline may vary, but not the transverse distance (see **Figure 1**).
- When checking for longitudinal streaking, the longitudinal distance from centerline will vary.

This is done so the profile will cross over the longitudinal streaks. Determine the transverse distance from centerline to the longitudinal segregation. Start the profile approximately 2 ft (0.6 m) farther transversely than the center of the longitudinal streak. End the profile approximately 2 ft (0.6 m) less transversely than the center of the longitudinal streak. The approximate distance (2 ft or 0.6 m) from the center of the streak to start and end the profile will be determined by the Engineer (see **Figure 1**). Pick a distance from either edge of which you believe will be most likely to detect segregation. That distance shall be more than 2 ft (0.6 m) from either edge of placement. Only one distance is to be used throughout the length of a single profile section for truck load segregation. When testing for longitudinal segregation, each end of the profile will be more than 1 ft (0.3 m) from the edge of paving. If there is no visible segregation, then randomly select the location for the profile section.

5. NUCLEAR GAUGE READINGS

Minus No. 30 (600 μm) aggregate from the mix will be used to fill any voids in the surface. Smooth and level the minus No. 30 (600 μm) material with a metal plate or straight edge. The aggregate is not to be used as a thin film between the hot mix and the gauge. Use only enough aggregate to fill the voids. (For this procedure, the aggregate shall be minus No. 30 (600 μm) material from the mix with no more than 20% passing the No. 100 (150 μm) sieve.

NOTE: For uniformity, position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

In backscatter mode, take 3 one-minute readings and average. If one of the readings varies by more than 1 lb/ft^3 (16 kg/m^3) of the average, then discard and take an additional reading to replace it. It is not necessary for the gauge to be calibrated to the mix.

Take a minimum of ten locations along the profile section. It is not necessary to maintain a rigid longitudinal spacing of 5 ft (1.5 m) as stated above. Remember to take additional readings if a segregated location is encountered along the profile.

NOTE: Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

6. PROFILE EVALUATION

Initially perform four segregation checks for each mix. When four consecutive profile evaluations meet the acceptable criteria established in the Contract Documents, the District Materials Engineer may reduce the segregation checks to a frequency deemed appropriate.

The contractor field representative will be provided results of the segregation checks as they are completed. When one of the segregation checks fails the acceptable criteria established in the Contract Documents, the contractor will be allowed to make changes to the mix, plant, or roadway operations before the next profile evaluation is made. If any changes are to be made by the contractor, these changes are to be made within the first hour of production following notification of a failing evaluation. Production of the hot mix is to cease whenever two consecutive checks fail. The contractor will make changes to the mix or process before production is restarted. The contractor may produce enough mix to place approximately 2000 ft (600 m) of pavement one paver width wide. Two segregation checks will be taken within this 2000 ft (600 m) of production. If both segregation checks meet acceptable criteria, the contractor may resume normal production. If one or both of the segregation checks fail, the contractor will make changes before production is restarted. The contractor may then produce enough mix for an additional 2000 ft (600 m) of pavement and this production will be evaluated as was the previous 2000 ft (600 m) of production. This procedure of placing and evaluating 2000 ft (600 m) sections will be continued until both segregation checks pass. Normal production and segregation checks will resume when both evaluations pass.

The drop in density caused by segregation will be calculated by subtracting the lowest density obtained from the average profile density. The average profile density shall be calculated using all density determinations in the profile section. The density range will be calculated by subtracting the lowest from the highest profile density.

7. SEGREGATION CHECK FORM

The **SEGREGATION CHECK USING THE NUCLEAR GAUGE** form provides the user a means of recording key information to pinpoint the location of the profile section. It also provides a chart for graphing the average recorded nuclear density readings.

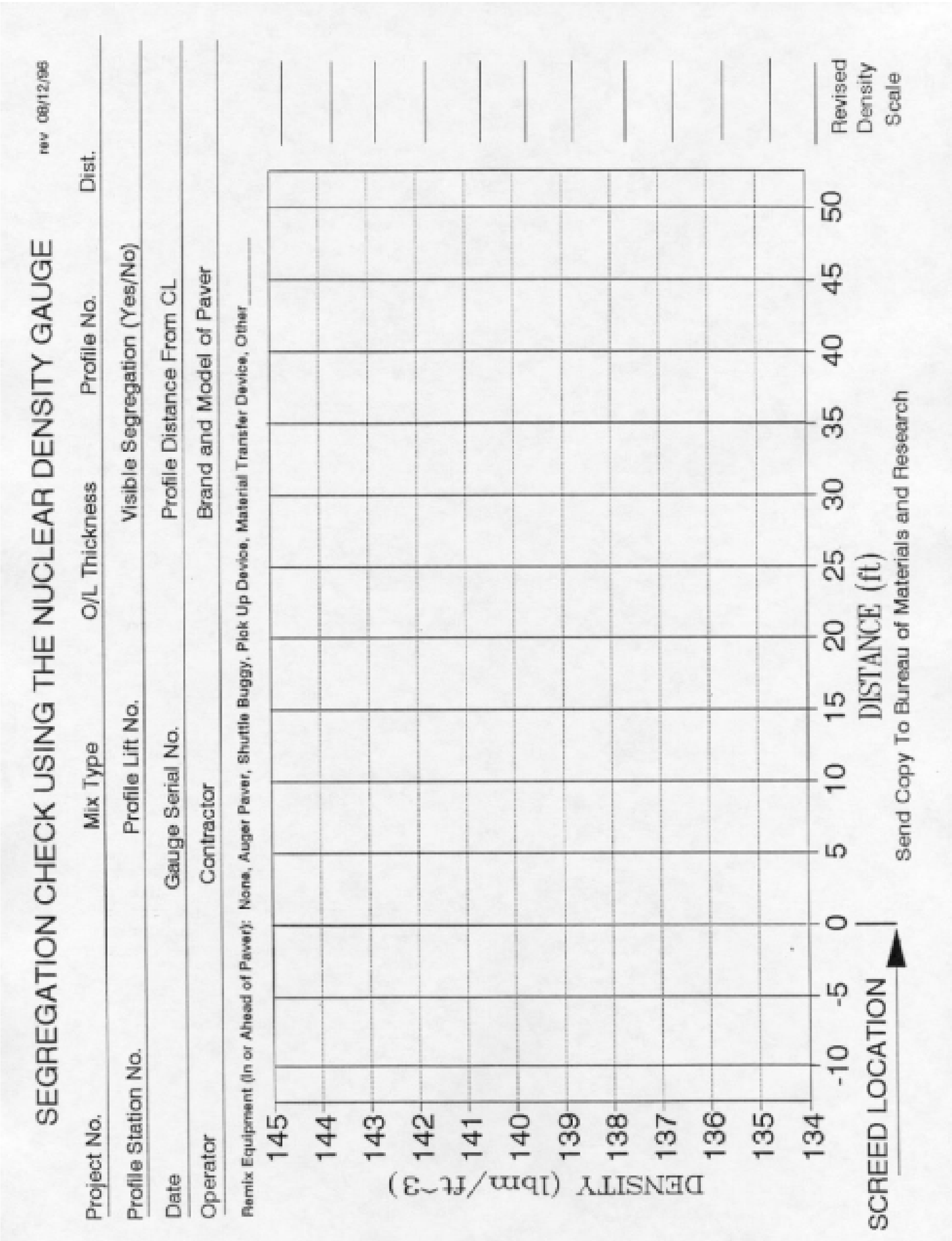
Note: the screed location is referred to as the zero point. When the paver is stopped, rollers are prevented from compacting all of the asphalt material that has been laid down. A portion of material has the chance to cool before being compacted. Recording the densities behind the screed provides the gauge operator a complete profile of possible low density locations.

On the right side of the chart is a location to place a different scale in case the left side does not fall in the density region of the material being profiled. If this side is used, cross out values on the left side to help eliminate any confusion.

8. DENSITY GAUGES AND TEMPERATURE

It is recommended to allow the compacted surface to cool for as long as possible prior to using the density gauge. Remove the gauge from the surface immediately after the readings have been taken.

Although the density gauge is designed for high surface temperatures [350°F (175°C)], the ambient temperature inside the gauge is not to exceed 160°F (70°C). If the gauge remains on the surface for any length of time, the surface temperature becomes the ambient temperature inside the gauge. This occurs when the surface temperature penetrates up into the electronics. The electronics can experience temporary malfunction or permanent damage due to excessive heat.



SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE

rev 08/12/98

Project No. ______ Mix Type ______ O/L Thickness ______ Profile No. ______ Dist. ______

Profile Station No. ______ Profile Lift No. ______ Visible Segregation (Yes/No) ______

Date ______ Gauge Serial No. ______ Profile Distance From CL ______

Operator ______ Contractor ______ Brand and Model of Paver ______

Remix Equipment (In or Ahead of Paver): None, Auger Paver, Shuttle Buggy, Pick Up Device, Material Transfer Device, Other ______

Send Copy To Bureau of Materials and Research

SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE

Rev 08/12/96

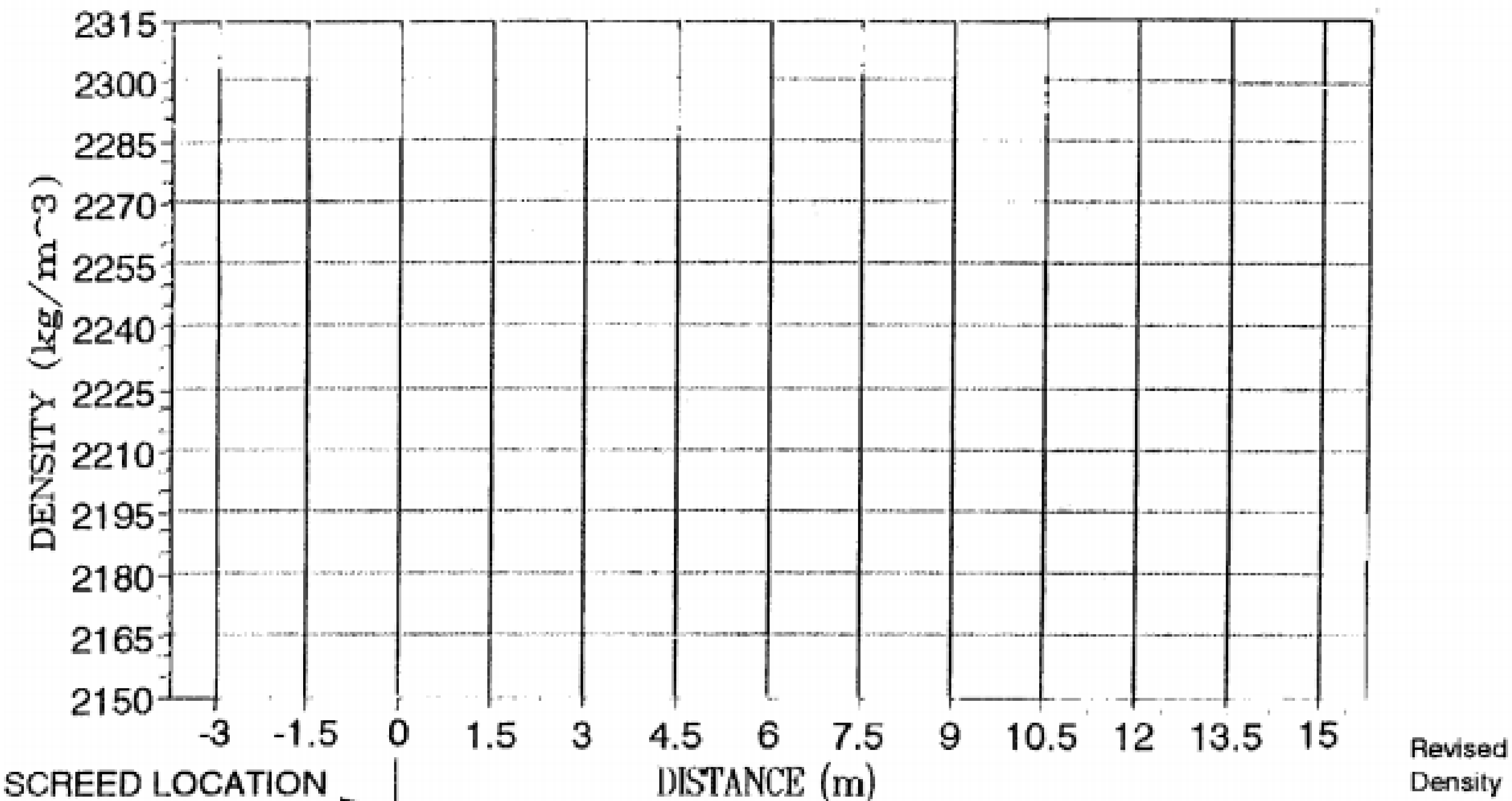
Project No. Mix Type O/L Thickness Profile No. Dist.

Profile Station No. Profile Lift No. Visible Segregation (Yes/No)

Date Gauge Serial No. Profile Distance From CL

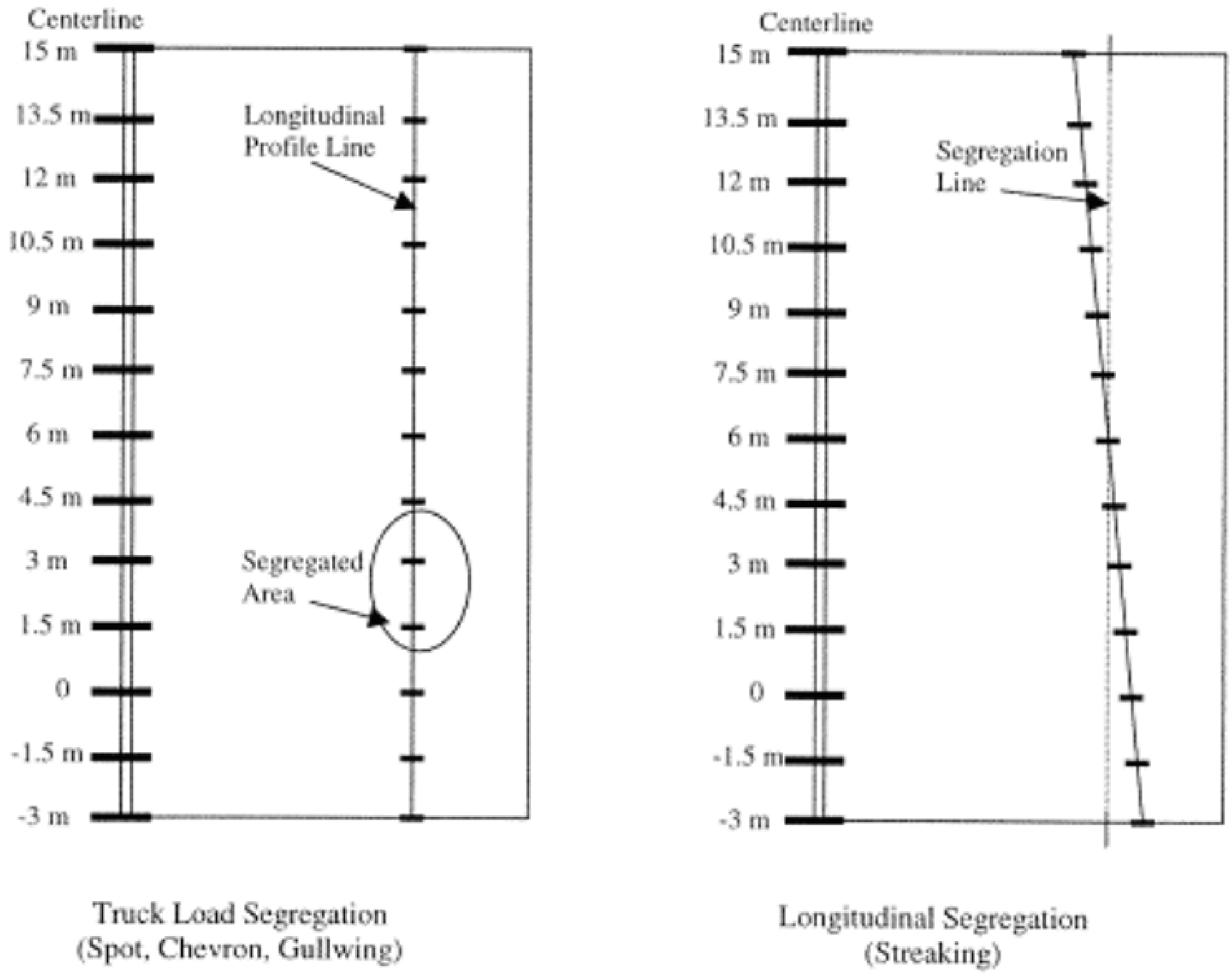
Operator Contractor Brand and Model of Paver

Remix Equipment (In or Ahead of Paver): None, Auger Paver, Shuttle Buggy, Pick Up Device, Material Transfer Device, Other



Send Copy To Bureau of Materials and Research

FIGURE 1: SEGREGATION PROFILE LOCATION



Q21 response: Segregation check points - https://dmsweb.ksdot.org/AppNetProd/docpop/docpop.aspx?clienttype=html&docid=8880852

SEGREGATION CHECK POINTS

STOCKPILES

- Avoid HIGH DRY CONES of coarse material. They guarantee segregation, it's just a question of how much..
- Low, flat piles or individual truck dumps are better.
- Visual inspection should detect stockpile segregation.

LOADING COLD BINS

- Some stockpile segregation can probably be corrected by the front end loader operation, but don't depend on it.
- The bins should be loaded evenly. Avoid the pile it high - run it dry syndrome. Cones and lop-sided loads will segregate just as they do in the stockpile.
- DO NOT allow material to slop over from one bin to the other.

COLD BIN OPERATION

- Bin openings should be high enough to prevent clogging. A large opening and a slow belt is the best combination.
- If one bin cannot properly handle the necessary material, you may have to split it into two bins.
- "Overworked" bins are prime sources of segregation.
- Gobs of wet material - for example: sand - should be smoothed out with a drag chain or other suitable means.

COLD FEED CONVEYORS

- Material coming off the end of a belt will segregate. The coarse material will be thrown out further than the fine.
- This is particularly obvious when one belt feeds another at an angle. Plates, baffles or other appropriate devices are necessary to prevent belt end segregation.
- Any segregation up to this point will show up on the cold feed belt going into the drum or dryer.
- Careful sampling at this point is very important - it can identify and/or isolate several potential sources of segregation.
- Remember, segregation can occur both along and across the belt. Proper sampling can detect either or both.

- Don't forget to look at the aggregate going off the belt into the drum or dryer. The coarse particles may be flying off by themselves. When you are recycling, there are two such points.

DRUM MIXER OR DRYER

- Don't expect the drum or the dryer to put segregated material back together again. They won't do it. In fact, they can be a source of segregation. Coarse material will pass through faster than the fine.
- Most drums are designed to operate at 1/2" to 3/4" drop per foot. The coarser the material, the flatter the slope should be. Don't overlook this item.
- Uncoated or partially coated material segregates worse than properly coated material. The location of the asphalt discharge in the drum is important. Moving the discharge point closer to the drum inlet may eliminate uncoated particles. Moving it too close can cause burning of the asphalt as evidenced by blue smoke.

HOT CONVEYORS (DRUM MIXER)

- The hot belt should be covered. Chilling the material on one side of the belt is a good way to promote segregation.
- Proper sampling of the material on the hot belt can determine whether segregation is occurring in the drum. (if you have previously determined that the material going into the drum is not segregated). Segregation can occur along or across the belt.

SLAT CONVEYOR (DRUM MIXER)

Slats should have enough capacity so material does not fall back down the conveyor after approximately the first 10 feet.
The output of the drum should deposit the material uniformly across the slats. Segregation has been observed across improperly loaded slats.

GOB HOPPER (DRUM MIXER)

Check this one carefully and often. Check the following points:

- The material should be directed into the hopper so it is spread out uniformly, not coned in the middle or stacked against the side.
- The hopper should be loaded as full as possible before the gates open.
- The gates should close before the hopper runs dry.
- The gates should open and close quickly enough to produce a "GOB", not a gentle trickle.

HOT BINS (BATCH PLANT)

- If the dry aggregate going into the bin, or bins, is not segregated, and the mix out of the pug mill is segregated, then whatever configuration of screens and bins you are using is segregating the material so badly that good pug mill operation can't remix it.
- If operating with only one bin, it should only be large enough to hold one batch at a time and it should be close to the middle of the pug mill.
- There is an optimum size batch for each pug mill - use it.
- Worn, missing or improperly adjusted blades should be replaced and/or adjusted.
- Mixing time should be adequate.

HOT CONVEYOR AND GOB HOPPER (BATCH PLANT)

Batch plants, drag slat conveyors and Gob Hoppers may be incompatible. Here is a scenario observed at a plant:

When a batch was augered across to the drag conveyor, the slats would grab more than they could handle and coarse aggregate would come rattling back down the chute in a steady stream. The last to go up was a slug of coarse material.

Meanwhile, the Gob Hopper was opening and closing on a cycle which had no relation to the batch cycle. Sometimes it would open when almost full, sometimes when in contained a few pebbles and sometimes the material flowed directly through the open gates.

The resulting mix was severely segregated.

Segregation was appreciably -reduced when trucks were loaded directly from the pug mill and the project was completed this way.

Because of the "stop and go"-mode of batch plants, drag conveyors should be capable of conveying without spilling back, and gob hopper cycles should be determined by weight instead of time.

SURGE BIN

- The bin should be plumb. There is evidence that tilted bins do segregate.
- The bin should never be operated "out of the cone". Gates must be locked when material draws down to the cone. Bypass of this lock is for cleanout only.
- One experiment showed that the height of the material in the surge bin has some influence on segregation.
- When the level of the bin was between one-half full and the top of the cone, segregation was less than when the level was between full and one-half full. The apparent reason was the longer drop of the "Gob" caused the material to splatter and distribute evenly across the bin instead of making a cone in the middle.
- The gates on the surge bin should open and close quickly.

LOADING TRUCKS

- This is a place where a little care may pay big dividends.
- AVOID SINGLE CONES - coarse material runs down the cone and collects along the sides and ends of the trucks.
- Every time you add material to a single cone, you add coarse material to the collection.
- Every one of those bits and dribbles added to "sneak up" on full load adds its bit to segregation.
- If you are serious about reducing segregation, instruct your scalesperson to keep those little bits to a minimum and don't let truck drivers load their trucks. They tend to push the button just because it's there.
- Multiple dumps are better than one large one. Use three dumps - front - back, then middle for tandems - about 3 ft. apart. It's not necessary, nor advisable, to overload the back axle. Longer trucks may require four or more dumps.
- Uncovered trucks may add to segregation.

TRUCKS TO LAYDOWN MACHINE

Here is probably the worst possible scenario:

A truck has just finished unloading. The coarse material which was in the front of the truck came out last and was moved back to the augers as the hopper was emptied. While that truck was unloading, the coarse material along the sides of the truck trickled out through the gap between the truck bed and the tailgate and came to rest on the hopper wings. As soon as the hopper was empty, the wings were dumped and the material moved back to the augers. The tailgate of the next truck is then opened and the bed slowly raised allowing the coarse material which is in the back of the truck to join the coarse material which was in the sides and front of the previous trucks.

The result of this phenomenon, which may occur at regularly spaced intervals, is usually visible, sometimes audible, and always detrimental.

Try the following:

- DO NOT empty the hopper after each load.
- Raise the truck bed before opening the tailgate and flood the hopper. Then, slack off and try to maintain an even flow out of the truck and through the laydown machine. Every time this flow is interrupted coarse particles trickle out onto the wings.
- Do not dump the wings into an empty hopper. If the wings are loaded with coarse material, NEVER dump them into the hopper.
- DO NOT empty the hopper after each load.

LAYDOWN MACHINE

- In the interest of reducing segregation and enhancing quality workmanship in general -AVOID THE "HURRY UP AND WAIT" SYNDROME
- The longer a laydown machine sits between loads the colder it and the material get. Cool material segregates worse than hot material.
- Augers running too fast will segregate coarse material.
- Maintain an even flow through the machine, don't over or under feed the augers run them as much as possible - 90 percent is a good goal. This requires the right combination of gate openings and limit switch settings.
- Check the paddles in the center of the screed for wear - they put the split material back together.
- Check the crown - It should be approximately 1/4" higher in front.
- Check for excess wear and looseness in adjusting screws.
- Check to see if the pull point on the screed is at the factory recommended height for the lift thickness.
- Check distance between screed and augers. Materials should feed down and not lay dormant.
- AND - don't segregate the centerline joint with rakes and lutes trying to correct for improper paver operation.

C & M 09-15-95
typographical corrections 09-03-98

Kentucky

SECTION 401 — ASPHALT MIXING PLANT REQUIREMENTS
401.02 EQUIPMENT.
401.02.01 All Asphalt Mixing Plants.
E) Mixer Unit for Batch Method. Include at the plant a batch mixer of an approved twin pugmill type. Ensure that the mixer does not leak or cause segregation during discharge.

403.03.05 Spreading and Finishing. Prevent segregation of the fine and coarse aggregates during all phases of construction. Spread the mixtures with a paver. Heat the screed uniformly throughout its length. Do not allow flames to directly contact the mixture. Adjust the paver speed to provide the best results for the mixture being used and to coordinate with the rate of delivery of the mixture to the paver to provide a uniform placement rate without intermittent operation. Operate the screed or strike-off assembly without tearing, shoving, or gouging the mixture when laying the mixture. Operate vibrating screeds or other compacting features of the paver according to the manufacturer's recommendations during the placement of the pavement.

. . .

Immediately after striking off and before rolling, visually inspect each course for irregularities, and correct if necessary. Keep hand raking of the mixtures to the absolute minimum. Ensure that the finished surface has a uniform appearance, free from segregated areas. Immediately remove and replace, as directed, all portions of a pavement course that are defective in mixture composition, show excessive segregation, or do not otherwise comply with the Contract.

Correct irregularities in alignment of the outside edge or edges of longitudinal joints by adding or removing material before compacting the edges.

Over uniform, narrow areas, such as widening or narrow, paved shoulders where the use of pavers would be impractical, spread by a mechanical spreader. Ensure that the material is placed to the required lines, grades, and cross section without segregation of the mixture.

Over areas where machine spreading is impractical due to irregularities or obstructions, spread the mixture by approved methods. Place the material to avoid segregation and to reduce to a minimum the amount of patching required during compaction. Discard all coarse aggregate particles brought to the surface by raking. Do not scatter or broadcast excess mixture or particles across the surface of the uncompacted mat.

Louisiana

Section 501 Thin Asphalt Concrete Applications

501.08 HAULING, PAVING AND FINISHING. Meet the requirements of 502.08 except as modified herein. Use fully sealed tarps on all loads. Load haul trucks to minimize segregation.
501.09 ROADWAY QUALITY ASSURANCE. The Department will perform all plant acceptance and verification testing to meet the Materials Sampling Manual. The Project Engineer will verify that the tack coat application rate and mixture yield meet the requirements of Table 501-1. Do not place asphalt concrete exhibiting deficiencies before placement such as segregation, contamination, lumps, non-uniform coating, excessive temperature variations, alignment deviations, variations in surface temperature or other deficiencies, apparent on visual inspection. Poor construction practices such as handwork, improper truck exchanges, improper joint construction, or other deficiencies, apparent on visual inspection, will not be accepted.

Section 502 Asphalt Concrete Mixtures

502.08 HAULING, PAVING AND FINISHING. . . .
Load haul trucks to minimize segregation.
502.08.2 Paving Operations: . . .
Construct longitudinal joints and edges along established lines. Utilize some form of longitudinal control for the paver to follow, preferably a string line. Position and operate the paver to closely follow the established line. Correct irregularities in alignment by trimming or filling directly behind the paver. Check the texture for uniformity after each load of material has been placed. Check the adjustment of screed, feed screws, hopper feed, etc., frequently and adjust as required to assure uniform spreading of the mix to proper line and grade and adequate compaction. When segregation of materials or other deficiencies occur, suspend paving operations until the cause is determined and corrected.

502.11 ROADWAY ACCEPTANCE. . . .

Do not place asphalt concrete mixture exhibiting deficiencies such as segregation, contamination, lumps, non-uniform coating, excessive temperature variations, or other deficiencies apparent on visual inspection.

Correct and/or replace at no direct pay any asphalt concrete mix exhibiting deficiencies, such as segregation, contamination, alignment deviations, variations in surface texture and appearance or other deficiencies, apparent on visual inspection. Poor construction practices such as handwork, improper truck exchanges, improper joint construction, or other deficiencies, apparent on visual inspection, will be corrected at no direct pay.

Section 503 Asphalt Concrete Equipment and Processes

503.03 AGGREGATES.

503.03.1 Stockpiles: Store aggregates at the plant site so that no intermixing, segregation, pooling of water or contamination will occur. Ensure that gradation and other properties of aggregate in stockpiles are combined in proper proportions so that the resulting combined gradation will meet the requirements of the approved JMF.

503.08.2 Storage Silos and Surge Bins: Use approved storage silos or surge bins for storing asphalt concrete mixtures. . . . Ensure silo or bin unloading gates are either clam shell gates operating under gravity feed or other approved gates that will not cause segregation or be detrimental to the mix.

503.09 SCALES AND METERS

503.09.2 Weigh Hoppers: Provide weigh hoppers to weigh the mixture or individual material components. Provide hoppers that do not leak or cause segregation.

503.14 MATERIAL TRANSFER VEHICLE (MTV). When placing the final two lifts of asphalt concrete on the roadway travel lanes, use a material transfer vehicle (MTV) or lightweight MTV to deliver mixtures from the hauling equipment to the paving equipment, and to minimize thermal and material segregation of the hot mix asphalt concrete.

Ensure that the MTV provides additional mixing of the asphalt concrete mixtures and then deposits the mixture into the paving equipment hopper to reduce segregation and facilitate continuous production. At a minimum, provide an MTV with a high capacity truck unloading system, which will receive mixtures from the hauling equipment; a 20 ton storage bin in the MTV to continuously mix the mixture prior to discharge to a conveyor system; a discharge conveyor, with the ability to swivel, delivering the mixture to a paving equipment hopper while allowing the MTV to operate from an adjacent lane. If the weight of the MTV is determined by the engineer to cause settlement or movement in the base or sub-base, discontinue use. If the problem persists with the use of a lightweight MTV, discontinue use of the MTV. When a malfunction occurs in the MTV during lay-down operations, immediately discontinue plant operations and do not resume until the MTV malfunctions have been remedied. Mixtures in the silo (≤ 100 tons) or materials in transit may be placed.

503.14.1 Lightweight MTV: The lightweight MTV has a smaller capacity, is more fuel efficient and may be used in lieu of the MTV. Lightweight MTV's must meet all requirements of the 503.14 MTV and as modified herein. Use a Thermal Profile system in accordance with section 503.14.3 at all times when a lightweight MTV is used in lieu of the MTV. Discontinue use of lightweight MTV when thermal segregation is observed

503.15 PAVERS. . . . Provide pavers capable of spreading mixes to required thickness without segregation or tearing.

Section 505 Asphalt Prime Coat

505.05 SURFACE PREPARATION. Shape the surface to be coated to required grade and section. Assure that the surface is free from ruts, corrugations, segregated material or other irregularities, and compact to required density.

Michigan

https://michiganltap.org/sites/ltap/files/publications/technical/MDOT%20-%202012%20Standard%20Specifications%20for%20Construction.pdf

101.03 Definitions
Segregation. Areas of non-uniform distribution of material components that are visually identifiable or can be determined by other methods.

Section 501. PLANT PRODUCED HOT MIX ASPHALT
501.01. Description. This work consists of providing and placing Hot Mix Asphalt (HMA) mix using Superpave Mixture Design Methods.
A. Terminology.
HMA Segregation. Areas of HMA pavement exhibiting non-uniform distribution of coarse and fine aggregate particles, visually or otherwise identifiable.

501.03. Construction.
A. Equipment.
4. Pavers. Equip each paver with a full-width vibratory or tamper bar screed capable of spreading and finishing HMA to the required cross section and grade. Use a paver that produces a uniformly finished surface, free of tears, other blemishes, and measurable segregation.
6. Spreaders. Use self-propelled spreaders capable of pushing the hauling units. Ensure spreaders can maintain the required width, depth, and slope, without causing segregation.

N. HMA Mix Acceptance. The Engineer will inspect field-placed material, perform QA sampling and testing, and monitor Contractor adherence to the HMA-QC Plan.
1. HMA Field-Placed Inspection. The Engineer will perform inspection acceptance of HMA.

The Department will inspect the base and leveling courses within 18 hours and the top course within 36 hours of placement. The Engineer will accept the pavement within these timeframes unless corrective action is required. If the Engineer determines that corrective action is required, inspection acceptance and paving of overlying courses will not occur until after the Contractor completes corrective action and the Engineer has determined that the pavement is in conformance with the contract.

The Engineer will determine the need for corrective action based on the acceptance factors specified in Table 501-5. Corrective action may include remedial treatment, including crack or surface sealing, or replacement.

Submit an action plan to the Engineer that addresses all acceptance factors that resulted in the need for corrective action. Complete all corrective action required to repair or replace unacceptable work at no additional cost to the Department.

If the Engineer and the Contractor agree, the Department may make a contract adjustment of no greater than 100 percent of the bid price for corrective action.

Table 501-5 HMA Acceptance Factors and Corrective Action				
Acceptance Factors (a)	**Length**	**Extent** (b)	**Severity**	**Corrective Action** (c)
Segregation	—	>215 ft²/ 328 ft LL	Heavy (d)	Replace
Rutting	—	>32 ft	>¼ in average depth over the length of occurrence	Replace
Flushing	—	>108 ft²/ 328 ft LL	High (e)	Replace
Edge of Paved Shoulder	>33 ft	visible ledges	>3 in	Trim
Crack (g)	any	any	all	Seal (f)

Note: LL = lane length.
a. Acceptance factors apply to all courses except flushing, which applies to the top course only.
b. Extent is calculated by summing locations within the length required.
c. The appropriate corrective action is dependent on the extent and severity of the factor, and on the intended service life of the pavement.
d. Segregation severity will be determinedin accordance with MTM 326. If segregation thresholds are met twice on a paving course, the Contractor may be required to use a Material Transfer Device for the remaining paving for that course at no additional cost to the Department.
e. Flushing must be severe enough to significantly effect surface friction (Friction Number <35).
f. Other corrective action may be required as crack frequency increases.
g. A reflective crack determined, by the Engineer, to be caused by an underlying condition.

Section 503. PAVER PLACED SURFACE SEAL
503.01. Description. This work consists of providing and placing paver placed surface seal (PPSS), including preparing existing pavement and constructing PPSS, uniform in texture, density, and smoothness with no measurable segregation.

Section 805. HOT MIX ASPHALT CURB
805.01. Description. This work consists of conditioning and treating the surface shown on the plans for placing Hot Mix Asphalt (HMA) curb, and constructing HMA curb.
805.03. Construction
C. Placing HMA Vertical Curb. The Engineer will not require rolling. Compact the mixture in the template form to the density required with the curbing machine. Provide a tight surface texture. Remove and replace curb that shows segregation, slumping, or misalignment, at no additional cost to the Department.

Q12 response: Michigan Test Method (MTM) 326
https://www.michigan.gov/documents/mdot_MTM_CombinedManual_83501_7.pdf

On page 226-227 of pdf:

MICHIGAN TEST METHOD
FOR
QUANTITATIVE MEASUREMENT OF HOT MIX ASPHALT (HMA) PAVEMENTS

1. Scope

This method shall be used to help assist the Contractor and Engineer in identifying segregation and taking corrective action to eliminate segregation when it is present in Hot Mix Asphalt (HMA) pavements.

2. Significance and use

2.1 This method requires the use of a nuclear density gauge and the MDOTMBITSEG2 computer program to assist in locating segregated areas and identifying limits of such areas. Contact the HMA Operations Unit at Construction Field Services for a copy of the MDOTBITSEG2 computer program. The HMA pavement materials shall be produced, transported, placed and compacted with the proper construction processes to provide uniform volumetric properties throughout the entire cross section of pavement.

2.2 This method may be used for:

2.2.1 Agency Acceptance Testing

2.2.2 Contractor Quality Control

2.2.3 Investigations

3. Equipment

3.1 Nuclear density gauge

3.2 MDOTMBITSEG2 computer program

4. Terminology

Segregation - Areas of Bituminous Pavement exhibiting non-uniform distribution of coarse and fine aggregate particles that is visually identifiable or can be identified by other methods.

Heavy Segregation - An area showing stone against stone, with little or no matrix visible.

Medium Segregation - An area showing significantly more stone than surrounding pavement with a lack of matrix.

5. Procedure

When heavy segregation is identified visually in the pavement by the Contractor or the Engineer, a set of six to fifteen one minute nuclear density measurements shall be taken by the Engineer in the segregated area, a similar set of readings shall also be taken in an adjacent non segregated area. The mean value of the density of the two areas shall be compared using MDOT's MBITSEG2 computer program. When it is determined that corrective action, as identified and recommended by the MDOTMBITSEG2 computer program, is needed, the Contractor shall implement corrective actions immediately and report them to the Engineer before the next day's paving begins. The Contractor shall also provide, in writing, the actions that will be taken to eliminate segregation. The Contractor, with the Engineer, shall closely monitor the in-place pavement when paving resumes. If, once paving resumes, heavy segregation is identified, the Contractor shall stop production and a complete evaluation of the manufacturing and paving process shall be completed. This evaluation shall follow the troubleshooting guide and suggested changes according to the equipment manufacturer's recommendations or the guide manual **AASHTO Segregation Causes and Cures for Hot Mix Asphalt**. Areas identified as heavy segregation by the MDOTMBITSEG2 computer program do not meet the Departments acceptance criteria for HMA pavement and full removal and replacement is required in these areas.

6. Measurement & Payment
No additional compensation will be made for corrective action required or operational changes to prevent segregation. This work will be considered as included in other contract items.

Minnesota

Q12 response: All layers use PMTP on travelled lanes.
http://www.dot.state.mn.us/materials/amt/specialprovisions.html

PMTP = Paver Mounted Thermal Profile [using infrared radar technology]. Judging from what is below, this is thermal imaging for detecting thermal segregation (though perhaps AC aggregate segregation might show up as different densities leading to different rates of cooling and some thermal variation). The first document is a memo related to adopting PMTP, and the second is a Pooled Fund study page, which is on intelligent compaction in general including PMTP as a way to automate QA/QC and collecting data during paving using a non-proprietary platform called ICDM-Veda.

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DEPARTMENT OF TRANSPORTATION

Office of Materials and Road Research
1400 Gervais Avenue
Maplewood, MN 55109

Memo

Date: January 9, 2018

From: Rebecca Embacher – Advanced Materials and Technology Engineer

RE: Intelligent Compaction (IC) and Paver Mounted Thermal Profile (PMTP) Deployment Schedule

Thank you for your assistance in helping us meet our deployment goals! This memo documents the current state of MnDOT's implementation effort of IC and PMTP technologies.

IC-PMTP Roadmap from 2014 through 2018

In 2014, a roadmap for deployment of IC and PMTP technologies was established as part of the Department's efforts to implement innovative technologies as a means of enhancing financial effectiveness. Numerous studies have been completed that evaluate the effects of uniformity on pavement performance. It has been repeatedly reported that the influence of spatial variability results in: increases in localized deflections, greater rutting depths and causes stress concentrations in the pavement, which lead to fatigue cracking (shorter fatigue lives) and other types of distress. A WSDOT study found that each one (1) percent of air voids in the pavement above seven (7) percent relates to one (1) year in loss of pavement life. Consequently, technologies such as intelligent compaction and thermal profiling will help the Department achieve greater uniformity in compaction efforts and as-built strength/stiffness properties. The roadmap generated in 2014 projected full deployment for IC and PMTP technologies for the 2018 construction season. In collaboration with Department staff, the Minnesota Asphalt Paving Association, Association of General Contractors, contractors, consultants and local vendors / industry, it is with great pleasure to report that *the Department is moving forward with full deployment this construction season*. These technologies are being deployed on projects meeting the following project selection criteria requirements as outlined in the MnDOT Pavement Design Manual (Chapter 8 Documentation):

Technology	Specification
Intelligent Compaction Method	2215 (Stabilized Full Depth Reclamation) 2331 (Cold In-Place Recycling Bituminous) 2331 (Cold Central Plant Recycling Bituminous) 2353 (Ultrathin Bonded Wearing Course) 2360 (Plant Mixed Asphalt Pavement) 2365 (Stone Matrix Asphalt)
Paver Mounted Thermal Profile Method	2360 (Plant Mixed Asphalt Pavement) 2365 (Stone Matrix Asphalt)
Project Selection Requirements: • ≥ 4 Net Lane Miles (and associated routes within the plan set, with a minimum, continuous length of 2-lane miles, unless waived by the Engineer); • Data cellular coverage (at least one time per day); and • 100 percent Global Navigation Satellite System (GNSS) coverage within project limits.	

As a result of the deployment efforts to date, we have already seen the following improvements on process control by contractors: reduced paver speeds, steps to reduce the number of paver stops, additional rollers added to the rolling train to assist with compaction efforts, modification of rolling patterns to increase uniformity of in-situ properties, asphalt delivery method changes/equipment considerations (e.g., use of pickup machines, re-mixers, etc.), increased fleet management with respect to the number of trucks and spacing of trucks delivering asphalt to the project, tarping of trucks to help mitigate cooling of the asphalt material, monitoring of stockpiles for moisture, requesting paving crew summaries, and more!

Anticipated Roadmap 2018 and Beyond

So, where are we going now? We will continue to put resources towards these technologies and associated tools. The following summarizes future deployment efforts and tasks for 2018 and beyond.

Year	Description
Winter 2018	***Lecturer-Led Veta Classes (Class #1)*** Provide Lecturer-Led Veta classes to Contractors and Consultants.
Winter 2018	***Lecturer-Led Veta Classes (Class #2)*** First year of Lecturer-Led Veta classes for Department, City and County Personnel. Objective of class is to teach agency personnel how to review submitted Veta projects and to discuss specification and construction highlights.
CY 2018	***PMTP Method – Pilot New Geospatial Statistic*** Pilot new geospatial statistic for identification of thermal segregation with the Paver Mounted Thermal Profile method. Anticipating 1-2 years for full deployment.
Winter 2019	***E-Learning Class Available Online Containing Veta Simulations*** Release of the E-Learning class has been pushed back to 2019 due to significant software improvements to Veta.
CY 2019	***District Review of Contractor Submittals*** The AMT unit will continue to review contractor submittals until construction year 2019, after which time, the Districts are expected to provide contract administration for review of contractor submittals related to the IC and PMTP method. The AMT unit will randomly review contractor projects in 2019 and beyond depending upon needs. The AMT Unit will refine the district review process during the 2018 construction season to ensure that it is documented and available for use prior to the start of district review in CY2019.

Year	Description
CY 2020	***Deployment of New IC and PMTP Submittal Requirements*** Veta projects and forms are currently submitted bi-weekly. The submittal requirements will be tightened in 2020. The Advanced Materials and Technology Unit will work with Department and Contractor personnel to determine a reasonable submittal schedule that is more frequent than the current requirements to allow for more near, real-time review of workmanship issues.
2018 to 2021	***Implementation of a Field Verification Method of PMTP Data*** The FHWA has determined that field verification of PMTP data is required for continued payment of incentives. The FHWA is currently evaluating how these requirements will be established and anticipates deployment of this requirement by construction year 2020/2021.
2018 to 2021	***Evaluate IC Measurements*** Determine IC parameters to potentially use as QC and/or QA.
2018 to 2023	***Rolling Density Meter (RDM)*** The rolling density meter is still in development. There will be pilot projects in 2018. Deployment efforts will be based upon outcomes of field trials. It is anticipated that this technology is 3 to 5 years out.
Research Needs	***IC Method – SFDR and CIR Applications*** Determine if IC stiffness values (ICMV measurements) can be used to evaluate compaction efforts on SFDR and CIR applications similar to a Proctor Curve. This would also allow for determination if re-rolling adds extra value.
Ongoing	***Integration of New Vendor Systems*** Continue to provide support for the integration of new vendor systems into Veta and construction.
Ongoing	***PMTP Method – Improvements to GNSS Accuracy*** Continue to work towards more accurate GNSS systems with the PMTP method. This would allow for an increased number of automated process within Veta and better correlations with other testing information (e.g., IC, core densities, material segregation, etc.).
Ongoing	***Veta Enhancements*** Continue to enhance Veta with automation, dashboards, performance improvements, etc.
Ongoing	***Streamline Deployment Efforts*** Continue to create tools, or enhance existing tools, to streamline the efforts needed to support the IC and PMTP technologies.

Again, we want to thank everyone for their time and resources put towards these deployment efforts and we look forward to continuing to work with everyone as the technologies continue to evolve.

MNDOT is also leading a Pooled Fund study on intelligent compaction and thermal profiling https://www.pooledfund.org/Details/Study/583 (ODOT is a partner – Vicky Fout is ODOT contact)

Study Detail View

Enhancement to the Intelligent Construction Data Management System (Veta) and Implementation

General Information

Study Number: TPF-5(334) View Commitment Details **Status:** Cleared by FHWA

Lead Agency: Minnesota Department of Transportation

Contract Start Date: **Est. Completion Date:** Dec 29, 2020

Solicitation Number: 1381

Partners: x , AK , AL , CA , CT , GADOT , IL , ME , MN , MO , MS , ND , NY , OH , OR , PADOT , TN

Related Study Number(s): PHASE-II OF VETA WILL BE DONE UNDER NRRA TPF-5(466

Contact Information:

Lead Agency Contact(s):

Debbie Sinclair
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FHWA Technical Liaison(s):

Matthew Corrigan
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Study Description

Background:
Intelligent construction data collection systems (i.e., geospatial systems such as intelligent compaction, paver-mounted thermal profiling [infrared radar technology], ground penetrating radar (GPR), and pavement smoothness/profile, etc.) gather large quantities of data each day of production activities. Near, ‘real-time’, integrated visualization and analysis systems are required so that materials and construction personnel can rapidly evaluate data and make decisions regarding acceptance.

Objectives:
Using ICDM-Veda as a tool/platform, the objectives of this effort are to incorporate features and enhancements such as the following:
• Analysis platforms
* Filtering, computations, modeling, etc.
• Management of database and project files
* Enhancements and additions to existing logic and coding to facilitate efficiency and added features;
• Mapping
* Mapping performance, print feature;
• Correlation analyses
* Correlations between different data sets (intelligent compaction, thermal profiling, GPR, pavement smoothness, FWD, density, etc.);
• Spot tests
* Management of conventional spot test data (import, filtering, mapping, correlations);
• Data import and mapping
* Import data sets from ProVAL, ground penetrating radar, and delimited text data;
• Contract administration
* Automated items needed to administer geo-spatial technologies during construction for QC/QA);
♣ - Data import/mapping, acceptance, basis of measurement and documentation of quantities;
• Asset management

* Mapping of final project QC/QA data collection for use as a supplement Pavement Management Systems

Scope of Work:
MnDOT, in collaboration with local contractors and suppliers, is moving forward with full implementation of geo-spatial technologies such as intelligent compaction and thermal profiling (infrared imaging) as quality control tools on grading, reclamation, and asphalt paving projects. Currently, only 10 to 15 percent of the MnDOT 2014 bituminous paving contracts will utilize these technologies due to lack of needed enhancements to the ICDM-Veda for use in contract administration.

MnDOT has spent $510,000 to date to create the ICDM platform and the features that are currently available. MnDOT is currently in the process of creating another contract worth $140,000 for enhancements that are needed for implementation during this 2014 construction season. This current platform is being used by nearly 20 other State Agencies for monitoring of geo-spatial projects using intelligent compaction. While these enhancements will be retained and built upon, there are numerous features that have yet to be added to allow for full monitoring, ease of use, automated procedures for cleaning/filtering of data and contract administration of these technologies by project personnel.

Intelligent Compaction is currently part of the Every Day Counts 2 (EDC2) initiative, with the objective of moving national implementation efforts of intelligent compaction forward. Consequently, ICDM-Veda, is included in the national training (and is referenced in the AASHTO Provisional Standard PP81-14 "Standard Practice for Intelligent Compaction Technology for Embankment and Asphalt Pavement Applications" and in the FHWA's boiler plate specifications), as it is currently the only non-proprietary tool available for State Agencies and Contractors to use to view spatial data.

In addition to investments to the EDC2 initiative, there has been a large amount of resources put toward researching this tool. The following are a few of the publications reported to assist with implementation efforts. Additional resources can be found at: http://www.intelligentcompaction.com/learn/resources/.

• Chang, G, Xu, Q, Rutledge, J, Horan, R, Michael, L, White, D, and Vennapusa, P, "Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials", FHWA-IF-12-002, Federal Highway Administration, Washington D.C. 2011.(FHWA TPF IC study final report)
• NCHRP 21-09 Intelligent Soil Compaction System (2006 to 2010) Final report is published as National Cooperative Highway Research Program (NCHRP) report 676: Intelligent Soil Compaction Systems in Jan. 2011. This report comes with 4 appendices: Appendix A, Appendix B, Appendix C, and Appendix D.
• Intelligent Compaction Implementation: Research Assessment, Joseph F. Labuz, Bojan Guzina, Lev Khazanovich, July 2008 http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1630
• Intelligent Compaction Monitoring Technology for Unbound Materials, David White, Mark Thompson, and Pavana Vennapusa, March 2007 http://www.lrrb.org/media/reports/200710.pdf
• Field Evaluation of Compaction Monitoring Technology: Phase II, David J. White, Mark J. Thompson, Kari Jovaag, Edward J. Jaselskis, Vernon R., Schaefer, E. Thomas Cackler, March 2006. http://www.intrans.iastate.edu/reports/compaction_2.pdf
• Intelligent Compaction and In-Situ Testing at MnDOT TH53, Lee Petersen and Ryan Peterson, March 2006. http://www.lrrb.org/media/reports/200613.pdf

In addition to intelligent compaction efforts under the EDC2, SHRP 2 is promoting national adopters for implementation infrared imaging for uniformity measurements under R06C "Technology to Enhance Quality Control on Asphalt Pavements". ICDM-Veda is currently the only non-proprietary tool for visualization and analysis of this technology.

Comments:
Recommended Funding: $265,000 to start with---total needed $550,000
We are looking for 6 states to contribute $25,000 per year for three (3) years

Missouri

Q7 response: The term 'segregation' is used throughout MoDOT's specifications, typically referring to the segregation of aggregates for use in concrete, asphalt, aggregate base, rock blanket or linings, and even in rock fill applications, but without official definition. Our Engineering Policy Guide (EPG) defines segregation in an asphalt mix as follows: Segregation is the separation of the aggregate in the mix resulting in areas with an undesirable gradation. See EPG discussion on segregation at:
http://epg.modot.org/index.php/460.7_Mat_Problems#460.7.10_Segregation

460.7.10 Segregation

Segregation is the separation of the aggregate in the mix resulting in areas with an undesirable gradation. Segregation results from the improper handling of the mix at any point during the production, hauling, and paving operations. It can occur as the mix is delivered from the plant to a surge silo, as the mix is discharged into the haul truck from the silo, and as the mix is deposited into the paver hopper by the truck. Some mixes are more prone to segregation than others. Mixes that have a large nominal maximum size aggregate, low binder content, or are gap-graded readily segregate when handled.

Rock pockets are areas of coarse aggregate that occur randomly across the length and width of the mat. They are generally caused by improper handling of the aggregate in the stockpiles and cold-feed bins or by improper storage of the mix at the plant. Rock pockets are more prevalent when the mix is produced by a drum-mix plant. If the loader places a bucketful of segregated aggregate in the cold-feed bin, the aggregate can pass through the drum, silo, haul truck, and paver without ever being completely mixed in with the other aggregate. This is possible because a drum-mix plant operates on a continuous-flow instead of a batch basis. Rock pockets generally do not occur in a batch plant because the screens and hot bins recombine any segregated material before it is fed into the pugmill. Further, the pugmill blends all the aggregates together, eliminating any segregation that might have occurred previously. However, if a surge or storage silo is used with a batch plant, segregation may occur because of improper loading of the silo. The solution to this type of segregation is proper handling of the mix at all times.

When a batch plant produces the mix, segregation may occur longitudinally on one side of the mat (side-to-side segregation) because of improper loading of the haul truck. If the mix is not delivered from the pugmill into the center of the width of the truck bed, the coarse aggregate particles in the mix may roll to one side of the truck and accumulate. When the mix is delivered to the paver, the segregated mix will be placed on the mat along the same side, and the segregation will appear as a longitudinal streak on that side of the mat. On the other hand, if a batch plant with a silo or a drum-mix plant produces the mix, segregation may occur on one side of the mat because of improper loading of the surge silo. As the mix is deposited into the silo, the mix is thrown to one side of the silo, and the coarse aggregate particles are separated from the finer materials. When the silo is emptied, the coarse aggregate is deposited into one side of the truck. This segregated material then passes through the paver and is seen on one side of the mat. Also, if the truck is not loaded in the center of its width, the coarse aggregate particles may roll to one side of the bed, and longitudinal segregation will appear on the corresponding side of the mat. One solution to this type of segregation is to load the mix directly in the center of the truck. If a silo is used for temporary storage of the mix, the necessary steps should be taken to ensure that the mix is deposited into the center of the silo.

Truckload-to-truckload segregation occurs at transverse locations across the width of the mat. The most common cause of truckload-to-truckload segregation is the improper loading of the haul truck from the silo. If mix is placed in the truck bed in one drop from the silo, the coarse aggregate particles in the mix have a tendency to roll to the front and back of the bed. Also, if the load is "topped off" by dribbling mix into the truck, segregation will occur. If the hopper or conveyors on the paver are emptied, or if the wings of the hopper are folded, after each truckload, any coarse aggregate particles that have accumulated near the tailgate of the truck will be deposited into the empty hopper and carried back to the auger chamber with the next load of mix. By loading the haul trucks with multiple drops of mix, truckload-to-truckload segregation can be significantly reduced by decreasing the distance that the coarse aggregate particles can roll. Also, the proper truck unloading procedures should be used to minimize any segregation that may have occurred in the truck loading procedure before it is introduced to the paver. Keeping the hopper full of mix between truckloads can also help reduce segregation. Using an MTV that reblends the mix can almost eliminate segregation.

Temperature segregation is also a concern. During the haul, the mix in the truck cools more quickly near the edge, bottom, and top of the load. If the cooler material is not remixed with the hotter material, variations in the temperature of the mat will occur. The results may be variations in mat density and surface texture. An MTV that reblends the mix can be used to significantly reduce temperature differences in the mat.

Segregation is extremely detrimental to the long-term pavement performance because the increased air void content of the mix in the segregated areas increases the potential for moisture damage. Further, the segregated areas are susceptible to raveling, and possibly, total disintegration under traffic. When segregation occurs, it is likely to lead to forms of long-term pavement distress such as wavy surface and poor compaction. Superpave - Lessons Learned provides additional information on causes and remedies for segregation.

https://epg.modot.org/files/3/3a/460_Figure_Superpave_Lessons_Learned_%28Segregation%29.pdf

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Superpave – Lessons Learned

By Ron Corun

This article is based on a presentation made by the author at the APA Asphalt Pavement Conference: Superpave 2003 during the World of Asphalt® 2003 Show and Conference in Nashville, TN.

Excerpted:

Lesson #6 – No Jail Breaks!

Segregation is a major concern when placing Superpave mixes. To prevent segregation you must keep the mix flowing in a confined mass from the HMA plant to the pavement. If you fail to provide this confinement ***at any point*** in the paving operation, the larger aggregate particles will make a jail break and run to the edges of the unconfined material.

Segregation may begin as soon as the large and small aggregate particles are mixed together inside the HMA plant drum. Segregation may also occur in the drag conveyor and storage silos. During loading of the delivery trucks at the HMA plant, the larger aggregate particles will break jail and run to the sides and edges of the truck body if proper loading procedures are not followed.

Trucks must be loaded in three drops. The first drop is placed against the front of the truck bed, which provides confinement. The second drop is placed against the tailgate, which prevents segregation at the back of the truck. The third and final drop is placed in the middle of the truck, using the first two drops as confinement. This procedure will prevent jail breaks from the HMA plant into the delivery trucks.

The next opportunity for a jail break is during the truck unloading into the paver hopper. The dump bed must be raised enough to place material against the tailgate, so that the material flows into the hopper as a mass. Continue to raise the bed as necessary to maintain a mass flow during the unloading process. *Never dribble material from the truck into the paver hopper!*

The paver hopper operation is another chance for a jail break. Coarser aggregate particles flow to the outside edges of the hopper wings. The hopper wings should only be dumped when the paver hopper is at least half full. This will allow the coarser particles to be blended back into the mix. *Never dump the hopper wings when the hopper is empty!*

The hopper deck should be covered at all times during the paving operation. Allowing the hopper to run empty after a truck has dumped will cause the coarse aggregate from the edges of the truck bed and paver hopper to be concentrated in one location in the mat. This is known as end-of-load segregation. If this process is repeated after each truck, segregation will appear as a recurring pattern in the roadway. This type of jail break can be prevented by keeping the hopper floor covered with mix at all times.

The paver feeder system provides several prospects for jail breaks. The auger drive box is located in the center of the two slat conveyors on most pavers. This provides an opportunity for coarse aggregate particles to dribble from the inside edges of the conveyors and run under the gear box, causing segregation in the center of the mat (centerline streak). This can be prevented by using diverter plates to force material from the inside edge of the conveyor back into the mass of mix, and then using reverser auger sections to force material under the gear box. These devices must be installed and well-maintained to prevent segregation in the center of the mat.

Feeder system operation must maintain a constant head of material in front of the screed to prevent segregation and to attain a smooth ride. Flow gates and feeder controls should be set to establish a constant, moderate speed for the conveyors and augers. If the speed is too slow, coarse particles can break jail as dribbling occurs. If the speed is too fast, the augers can sling the large aggregate particles out of the mix.

HMA mix needs to be moved from the conveyors to the end gates as a mass to prevent segregation, regardless of paving width. If coarse aggregate particles are allowed to break free and dribble to the end gate, segregation will occur at the longitudinal joint. Segregation at the end gate causes poor joint density and can lead to premature failure. Paving with the screed extended beyond the paver main frame requires the use of auger extensions and auger tunnel extensions to prevent a jail break at the edges of the mat.

Material Transfer Vehicles (MTVs) are increasing in use because they eliminate some of the jail break opportunities. These machines can remedy HMA plant, storage silo, and truck loading segregation by remixing the HMA. MTVs also reduce the opportunity for jail breaks from trucks unloading into the hopper and from hopper operation.

Many specifying agencies are convinced MTVs are a cure-all for all paving problems. They can make the placement of quality pavements easier, but laydown “best practices” must still be followed. An MTV cannot correct a segregation problem between the hopper and the screed.

Q12 response: 1) MoDOT Test Method TM 75 - Determining Segregation Using the Nuclear Density Gauge. https://epg.modot.org/index.php/106.3.2.75_TM-75,_Determining_Segregation_Using_the_Nuclear_Density_Gauge 2) The specification for asphalt/bituminous treated base mixes do not address segregation.

← MODOT Policy Guide logo looks like Wikipedia

106.3.2.75 TM-75, Determining Segregation Using the Nuclear Density Gauge

Jump to navigation Jump to search

This test method determines segregation of bituminous mixtures with the nuclear density gauge.

106.3.2.75.1 Procedure

Establish a 50 ft. profile containing the suspected segregated area and take density readings every 5 ft. or a fraction thereof along a longitudinal direction. The longitudinal direction can be straight or at an angle depending on whether the segregation is across the pavement or longitudinally. When testing keep the center of the gauge at least 1 ft. from the confined joint and 2 ft. from the unconfined joint.

Using the nuclear gauge in the backscatter mode, take 2 one-minute density readings at each location and average the results. If one of the readings varies by more than 1.0 PCF from the average, take an additional reading. Average the two closest readings and check if they are within 1.0 PCF and discard the other result. The nuclear gauge should be left in the same position when multiple readings are taken. The nuclear gauge does not need to be calibrated to the mix.

Take readings at a minimum of 11 locations along the profile section.

106.3.2.75.2 Calculations

From the data retrieved in the procedure, determine the highest density reading, the lowest density reading, the average profile density, the drop in density and the maximum density range.

Drop in density is the average profile density minus the lowest density.

Maximum density range is the highest density minus the lowest density.

106.3.2.75.3 Criteria

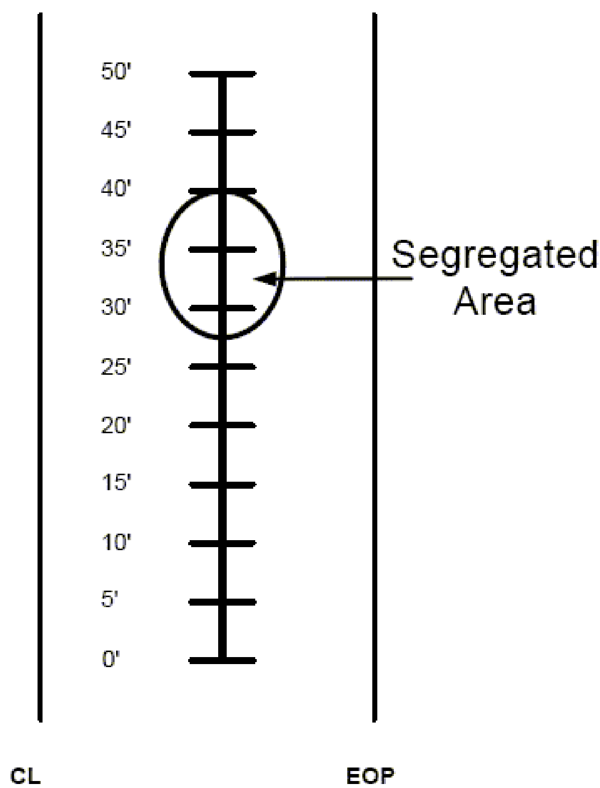
When a profile section is taken, both values are evaluated independently and addressed accordingly.

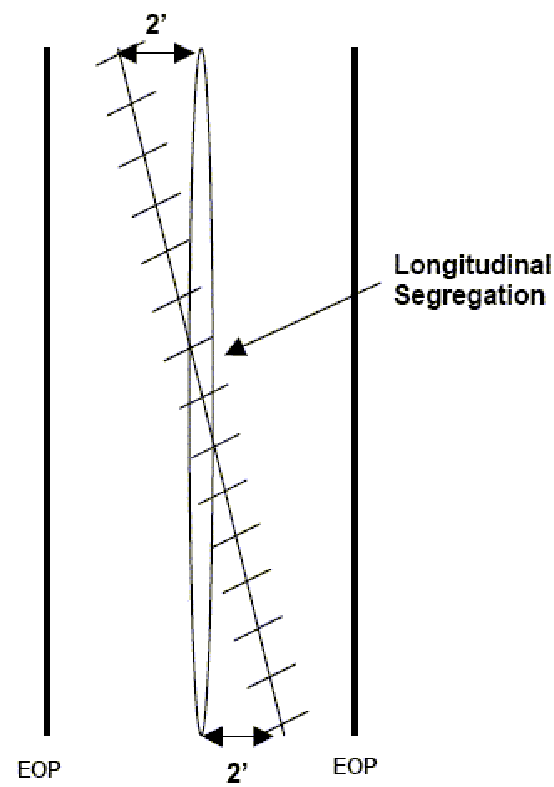
	Not Segregated	Action Taken	Remove and Replace
Max. Density Range	< 7.0	= or > 7.0 & < 9.0	= or > 9.0
Drop Density	< 3.5	= or > 3.5 & < 4.5	= or > 4.5

If a value falls in the “Action Taken” column, then segregation is evident and immediate action shall be taken by the contractor to resolve the issue; however, the severity of the segregation does not warrant removal and replacement. It is not the intent that production will continue day after day when results are in the “Action Taken” range.

106.3.2.75.4 Example

Identify area of concern and establish a 50 ft. profile through this region.





Take two density readings at each spot and average the results. If one of the readings is not within 1.0 PCF of the average, take an additional reading. Average the two closest readings and check if they are within 1.0 PCF and discard the other result. Record the data and average the results for each location, as shown in the table below.

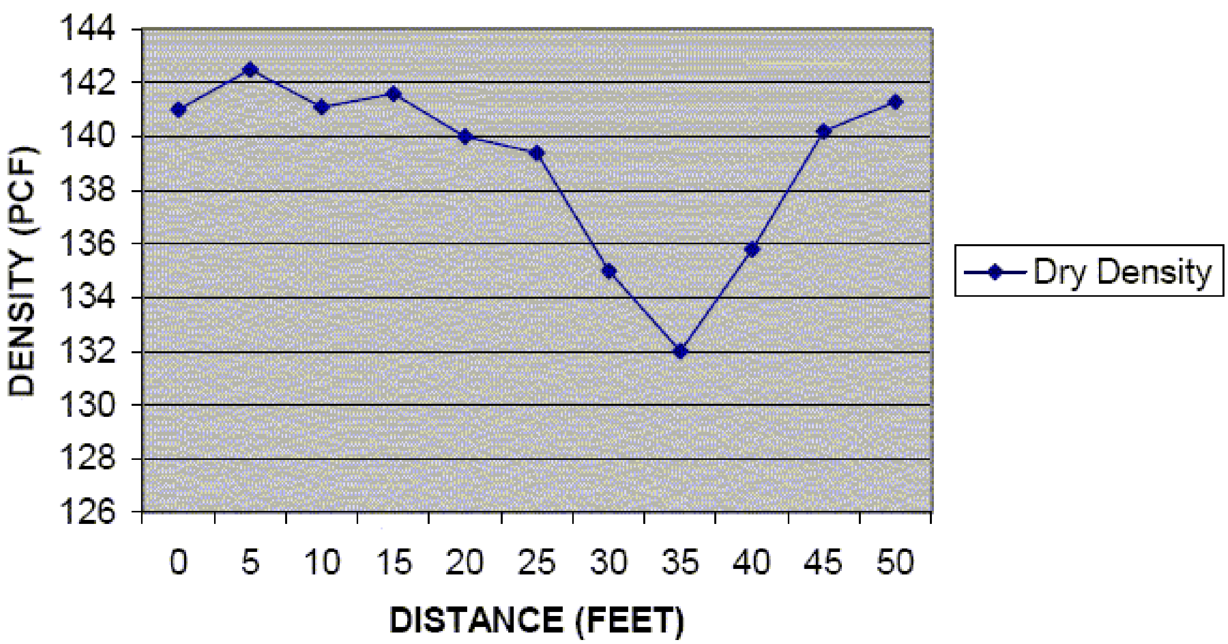
Table 106.3.2.75.4.1

Distance (ft.)	Readings (PCF)	Average (PCF)
0	140.8 & 141.1	141.0
5	142.1 & 142.9	142.5

10	140.2 & 141.9	141.1
15	140.6 & 142.6	141.6
20	140.2 & 139.7	140.0
25	139.1 & 139.7	139.4
30	135.1 & 134.9	135.0
35	132.3 &131.7	132.0
40	136.4 & 135.2	135.8
45[1]	~~137.7 &~~ 140.3 & 140.0	~~139.0~~ 140.2
50	141.7 & 140.9	141.3

[1] At 45 ft. the first two readings had more than a 1.0 PCF difference from their average of 139.0. Another reading was taken and in this particular case the first value was discarded and a new average was determined.

If desired, plot the density verses distance to give a graphical presentation of the area in question.



From the average density results pick out the highest and lowest results and compute the average density, as shown in the table below.

Table 106.3.2.75.4.2

Field Data	Density (PCF)
Highest Density	142.5
Average Density	139.1
Lowest Density	132.0

Compute the maximum density drop and the maximum density range and check for compliance.

The maximum density drop is the average density minus the lowest density:

139.1 – 132.0 = 7.1

The maximum density range is the highest density minus the lowest density:

142.5 – 132.0 = 10.5

The area in question requires removal and replacement according to the values obtained. It only takes one of the two criteria to fail before action must be taken.

106.3.2.75.5 Precautions

The nuclear density gauge is designed for high surface temperatures; however, the temperature inside the gauge is not to exceed 160° F. If the nuclear gauge is being used before the asphalt pavement has had a chance to cool down, remove the gauge from the surface immediately after the readings have been taken. If the temperature inside the gauge exceeds the 160° F, the nuclear gauge can experience temporary malfunction or permanent damage.

Category: 106.3.2 Material Inspection Test Methods

This page was last edited on 1 July 2010, at 08:13.

New York

Q21 response: See page 402-18. https://www.dot.ny.gov/main/business-center/contractors/construction-division/construction-repository/murk1b_cim.pdf

SECTION 402 – HOT MIX ASPHALT (HMA) PAVEMENTS

VIII. HMA PLACEMENT RESPONSIBILITIES

The Contractor is responsible to safely construct a HMA pavement that meets density requirements and is free of "shallow ruts, ridges, other irregularities, or roller marks in the pavement." The assignment of these responsibilities to the Contractor is logical because the Contractor and supplier have primary control of the quality of the asphalt mix, the traffic control, and the placement and compaction of the pavement.

The performance of HMA pavements is largely dependent on the in-place density achieved during construction. This is the reason in-place density is the measured quality parameter in NYSDOT's performance related HMA specifications. Require the HMA be compacted within certain specified density limits, as determined by cores or Density Gauge monitoring. The Contractor is given wide discretion in how to compact the pavement to achieve the required density, including equipment selection, setup, and operation. Long term HMA pavement performance is also significantly impacted by cracking, segregation, and other surface irregularities which may occur during construction. Ensuring the finished pavement surface is free of these problems is also the responsibility of the Contractor.

The contractor must provide a finished pavement mat that is free of surface irregularities. If these imperfections are present, correct the imperfections or remove and replace the pavement at no additional cost to the Department. The specifications state "the loose mat should be checked, any irregularities adjusted, and all unsatisfactory material shall be removed and replaced," and "remove any mixture that becomes loose and broken, mixed with dirt, or in any way defective and replace with fresh hot mixture and compact to conform with the surrounding area."

It is clearly the responsibility of the Contractor to obtain the required surface conditions as well as the specified density. NYSDOT inspection personnel will monitor these requirements on all projects. Specifically, inspection personnel should pay particular attention to the following:

1. HMA shoving which results in pavement cracking or tearing, even if the cracks or tears appear to heal during the compaction operation.
2. Mat spread resulting in an irregular longitudinal joint.
3. Segregation, especially segregation associated with the beginning and end of asphalt loading into the paver.
4. Surface irregularities, such as standing waves, longitudinal roller marks, closely spaced transverse roller depressions or areas of broken aggregate.

These non-density problems result in a poor riding surface and have a negative impact on the long-term pavement performance. Therefore, attention must be paid to the quality of the mat immediately behind the paver and quick action taken to correct problems.

If any significant areas or repeated smaller areas of a pavement exhibit any of these non-density problems, a progressive course of action should be taken. Common sense should be used when determining what is a significant area or repeated smaller areas. The key factor in judging what constitutes repeated smaller areas is that the defect continues to occur periodically or randomly more than several times in the HMA pavement. Examples of repeated smaller areas of defects would be persistent truck end segregation, or continuing random areas of any of the defects mentioned previously. The Construction Supervisor and RME should be consulted if there is any question as to determining if an area or areas require correction.

XI. MAT PROBLEMS AND POSSIBLE SOLUTIONS

NON-UNIFORM TEXTURE	
BLISTERS	
POSSIBLE PROBLEM	**POSSIBLE SOLUTION**
Moisture in underlying mat or grade	Allow mat or grade to dry before paving
Moisture in HMA	Contact Regional Materials Unit and HMA supplier
POOR SURFACE TEXTURE	
POSSIBLE PROBLEM	**POSSIBLE SOLUTION**
Worn screed plate	Replace screed plate
Cold screed plate	Check screed heaters
Screed vibration	Check if screed vibration is operating or needs adjusting
Change in HMA temperature	Contact Regional Materials Unit and HMA supplier
Change in HMA mix proportions	Contact Regional Materials Unit and HMA supplier
Aggregate size too large for thickness of mat	Increase mat thickness and contact materials to check for stockpile/bin contamination or a hole in a screen.
Excessive raking or walking on loose mat	Use proper paving procedures
Random segregation	Contact Regional Materials Unit and HMA supplier
Centerline segregation	Contact Regional Materials Unit and HMA supplier
Edge segregation	Check if reverse augers or kick back paddles at gear box are worn or need cleaning
End of truck segregation	Contact Regional Materials Unit and HMA supplier
	If screed is extended, require the use of an auger confinement tunnel
Surface shadows	Do not dump hopper wings after each truckload Dump hopper wings when hopper is 1/3-1/2 full of HMA so segregated material gets re-mixed
	Do not overload augers with HMA HMA level should be at auger shaft during paving

JOINTS	
LONGITUDINAL	
POSSIBLE PROBLEM	**POSSIBLE SOLUTION**
Poor joint compaction	Roll joint before HMA cools Check HMA temperature Use proper overlap of joint Check for edge segregation Inadequate compaction effort
Poor vertical joint alignment	Check set up and operation of joint matching shoe Provide proper loose mat thickness Use proper overlap of joint Check for edge segregation Check for fluctuating head of material Improper raking of joint
TRANSVERSE	
POSSIBLE PROBLEM	**POSSIBLE SOLUTION**
Rough or uneven joint	Incorrect joint preparation Put paver screed on starting blocks and provide proper amount of HMA in auger chamber when pulling off transverse joint Check screed plate heaters Improper raking of joint Check for segregation Roll joint transversely

POOR COMPACTION	
POSSIBLE PROBLEM	**POSSIBLE SOLUTION**
Poor underlying layer	Use proper pavement preparation
Poor quality HMA production	Contact Regional Materials Unit and HMA supplier
Change in HMA temperature	Contact Regional Materials Unit and HMA supplier
HMA segregation	Contact Regional Materials Unit and HMA supplier
Rolling too fast or not soon enough	Use proper paving practices
Improper number of rollers and/or choice of rollers	Use proper rolling procedures
Improper rolling pattern	Use proper rolling procedures
Improper operation of rollers	Use proper rolling procedures

February 2019 New York State Department of Transportation
402-29

Construction Inspection Manual

Ohio

Construction and Materials Specifications, April 16, 2021

400 FLEXIBLE PAVEMENT ITEM

401 ASPHALT CONCRETE PAVEMENTS — GENERAL

401.01 Description

Control all production processes to assure the Engineer that the mixture delivered to the paving site is uniform in composition, conforms to the specification requirements and that the placed mixture is free of any defect (ex. segregation, tenderness, lack of mixture and texture uniformity, raveling, flushing, rutting, holes, debris etc.) within the Contractor's control at project completion.

401.03 Materials.

Take prompt corrective action if mixture delivered to the paving site is not uniform in composition, does not conform to the specification requirements or is not free of any defect (ex. segregation, tenderness, lack of mixture and texture uniformity, raveling, flushing, rutting, holes, debris etc.) within the Contractor's control as determined by the Engineer. The Engineer will stop conditional acceptance of the asphalt concrete for failure to correct problems.

401.11 Hauling.

Before loading, apply a thin coating of an approved release agent to the inside surfaces of the truck bed to prevent adhesion of mixture to the bed surfaces. OMM maintains a list of approved release agents. Do not use fuel oil for this purpose. Drain truck beds after applying the release agent and before loading. Load trucks in manner to minimize segregation of the mixture according to the approved QCP. Any use of non-approved release agent, diesel, or fuel oil may result in suspension of truck, driver, or both for up to one year.

401.12 Spreading Equipment. Use self-contained spreading equipment of sufficient size, power, and stability to receive, distribute, and strike-off the asphalt concrete at rates and widths meeting the typical sections and other details shown on the plans. Use spreading equipment that has automatic control systems that maintain the screed in a constant position relative to profile and cross-slope references. Ensure control of the screed position is reasonably independent of irregularities in the underlying surface and of the spreader operation. Equip asphalt spreading equipment to prevent the segregation of coarse aggregate from the remainder of the asphalt concrete when the material moves from the hopper to the screed. Use means and methods approved by the asphalt spreader manufacturer consisting of but not limited to any combination of chain curtains, deflector plates, or other such devices.

. . .

Anti-Segregation Equipment. When specified, provide a Material Transfer Vehicle (MTV) with paver hopper insert; a Material Transfer Device (MTD) with paver hopper insert; or a remixing paver specifically manufactured to eliminate segregation. Use paver hopper inserts with a minimum capacity of 10 tons (9 metric tons). Remixing may be done by the MTV or MTD, in the paver hopper insert, or by the remixing paver. Provide and operate equipment in a manner that does not result in physical segregation, and limits temperature differentials to less than 35 °F (20 °C) throughout the mixture. Use anti-segregation equipment when paving intermediate and surface courses on all mainline lanes of the traveled way including express lanes, collector-distributor lanes, continuous center turn lanes, acceleration/ deceleration lanes, and ramp lanes. On the first day or night of paving any JMF, perform a test strip of a minimum of 1000 ft (300 m) in length. Notify the Engineer a minimum of 24 hours prior to performing the test strip. Demonstrate to the Engineer that the selected equipment is not physically segregating the mix and consistently limits the temperature differential of the mat surface, measured transversely, to

35 °F (20 °C) or less. Document results of each test strip on Department form CA-FP-5. Remove equipment or JMF that provides a mat with physical segregation, does not meet the temperature differential requirement, or both. Perform a new test strip any time placement equipment or JMF is replaced. If the Contractor is unable to produce a satisfactory test strip in two attempts per JMF, cease paving and provide a written plan to the DCA for approval prior to continuing the paving operation. Cease the paving operation in the events of; equipment breakdown, inability to consistently provide a mat free of physical segregation, inability to consistently meet the temperature differential requirements, or any combination. Do not resume paving until equipment is replaced with suitable equipment. The Engineer may allow paving to continue if an isolated area of mat temperature differential is in excess of 35 °F (20 °C). The Engineer may require additional evaluation of the area to determine the acceptability of the material.

401.15 Spreading, Finishing and Night Work

Take prompt corrective action if placed mixture exhibits any defect (ex. segregation, tenderness, lack of mixture and texture uniformity, raveling, flushing, rutting, holes, debris etc.) within the Contractor's control and as determined by the Engineer. Remove and replace, or otherwise correct in a manner satisfactory to the Engineer, any portion of the pavement course found to be defective in surface texture or composition before or after compaction.

. . .

When the total project includes more than one continuous lane mile (including bridges) of surface course paving in combination with night paving, and no pay item for anti-segregation equipment, provide anti-segregation equipment according to 401.12, for only the surface course. No additional payment will be made for this anti-segregation equipment.

ITEM 403 ASPHALT CONCRETE QUALITY CONTROL AND ACCEPTANCE

403.03 Quality Control Program (QCP).

Create and implement a Quality Control Program (QCP) for each paving season. The QCP will cover processes conducted to provide an asphalt mixture at the paving site that is uniform in composition, conforms to the specification requirements and that when placed is free of any defect (ex. segregation, lack of mixture and texture uniformity, raveling, rutting, holes, debris etc.) within the Contractor's control at project completion.

. . .

As a minimum include in the program:

N. Define the roles and responsibilities of the Field Quality Control Supervisors. Provide a detailed description of how the FQCS will handle all mat issues including segregation, tenderness, mat tears, debris, holes, etc. List approved Field Quality Control Supervisors.

For 448 acceptance mixes, conform to the procedures of Supplements 1035, 1038, 1039, and 1043. ~~except take samples from a truck at the plant. The District may require sampling from the road. If workmanship problems continue on the project (segregation, etc.) or if quality control problems persist, District Testing may require sampling on the road according to Supplement 1035~~.

ITEM 408 PRIME COAT

408.06 Preparation of Surface. Shape the surface to be primed to the required grade and section. Ensure the surface is free from all ruts, corrugations, segregated material or other irregularities and is smooth and uniformly compacted at the time of application of the asphalt material.

421.13 Acceptance.

The Engineer will base acceptance of the binder-to-dry aggregate proportion and spread rate on the Engineer's summary of quantities used each day. The Engineer will approve and accept a day's application of microsurfacing provided:

E. The pavement is uniform in composition and texture, free from excessive scratch marks, tears, rippling and other surface irregularities (segregation, raveling, rutting, holes, debris, etc.), longitudinal joints and lane edges coincide with any lane lines and edge lines and transverse joints are uniform, neat and provide a smooth transition.

ITEM 441 ASPHALT CONCRETE - MIX DESIGN AND QUALITY CONTROL

441.01 Description. This work consists of constructing a surface course or an intermediate course of aggregate and asphalt binder mixed in a central plant and compacted on a prepared surface. . . .

Control all production processes to assure the Engineer that the mixture delivered to the paving site is uniform in composition, conforms to the specification requirements and that the placed mixture is free of any defect (e.g. segregation, tenderness, lack of mixture and texture uniformity, raveling, flushing, rutting, holes, debris etc.) within the Contractor's control at project completion.

When specified, provide anti-segregation equipment for all courses of uniform thickness in accordance with 401.12.

441.12 Mixture Deficiencies. Control all production processes to assure the Engineer that the mixture delivered to the paving site is uniform in composition; within the specification requirements and limits; conforms to the JMF: and that the placed mixture is free of any defect (ex. segregation, tenderness, lack of mixture and/or texture uniformity, raveling, flushing, rutting, holes, debris etc.)

441.14 Basis of Payment. The Department will pay for accepted quantities at the contract prices as follows:

Item	Unit	Description
441	Cubic Yard (Cubic Meter)	Anti-Segregation Equipment

ITEM 442 SUPERPAVE ASPHALT CONCRETE

442.01 Description.

When specified, provide anti-segregation equipment for all courses of uniform thickness in accordance with 401.12.

441.08 Basis of Payment. The Department will pay for accepted quantities at the contract prices as follows:

Item	Unit	Description
442	Cubic Yard (Cubic Meter)	Anti-Segregation Equipment

ODOT Pavement Design and Rehabilitation Manual, January 2020

https://www.dot.state.oh.us/Divisions/Engineering/Pavement/Pavement%20Design%20%20Rehabilitation%20Manual/PDM_Section_400.pdf

406.3.2 Item 302 Asphalt Concrete Base, PG64-22

This item is to be used in conjunction with both a surface and intermediate course. This mix was developed for use with thick flexible pavements where high volume truck traffic exists. When lift thicknesses and maintenance of traffic operations allow, Item 302 is preferred over Item 301. Item 302 generally costs less than Item 301 and is a more stable, rut-resistant mix but is more susceptible to segregation problems during construction unless good construction practices are followed.

p. 400-10:

406.6 Anti-Segregation Equipment

Items 441 and 442 have a pay item for anti-segregation equipment. This item requires the contractor to provide equipment to remix the asphalt concrete after discharging from the trucks.

Anti-segregation equipment is to be specified for surface and intermediate courses of uniform thickness on all large-scale priority system paving projects. Large-scale paving projects generally consist of at least one mile (1.6 km) of paving. Other projects such as bridge projects that may include small amounts of paving do not need to specify anti-segregation equipment.

The cubic yards (cubic meters) calculated for this item should include the total quantity of surface and intermediate course on the priority system route driving lanes, C-D lanes, ramps, etc., but not including shoulders.

Pennsylvania

Q7 response: Pattern Segregation. Pattern segregation is continuous or repeated areas of non-uniform distribution of coarse and fine aggregate particles in the finished mat. See current PennDOT Publication 408, Specifications, Section 413.3(h)3. Pattern Segregation (http://www.dot.state.pa.us/public/PubsForms/Publications/Pub_408/408_2020/408_2020_2/408_2020_2.pdf). The Pub. 408, Specifications also addresses Flushing. See link and Section 413.3(h)4. Flushing

Section 413.3(h)3. Pattern Segregation (starting p. 413-16)

3. Pattern Segregation. Pattern segregation is continuous or repeated areas of non-uniform distribution of coarse and fine aggregate particles in the finished mat. The Department will address pattern segregation as follows:

3.a Evaluating Pattern Segregation. If the Representative observes pattern segregation that may result in defective pavement, then:

- The Inspector will notify the Contractor of the observed pattern segregation.
- The Contractor may continue to work at their own risk while immediately and continually adjusting the operation to eliminate the pattern segregation from future work.
- As a minimum and in the presence of the Representative, determine the average depth of pavement surface macrotexture according to PTM No. 751 in areas with the pattern segregation and in areas with non-segregated pavement. The pattern segregation is unacceptable if the difference in average pavement texture depth between the non-segregated and segregated areas exceeds 0.024 inch. The Representative will determine if the pavement is defective as specified in Section 413.3(h)3.c.

3.b Test Section. If the macrotexture tests identify unacceptable pattern segregation, then:

• Immediately suspend placing the asphalt course. Evaluate the cause of pattern segregation according to the Paving Operation QC Plan and as directed. Provide proposed corrective actions to the Representative and do not resume placing the asphalt course until after the Representative reviews the proposed corrective actions and authorizes paving to continue.

• Determine if the pattern segregation resulted in defective pavement as specified in Section 413.3(h)3.c.

• After the Representative allows paving to resume, place a test section not to exceed 200 tons. If the corrective actions do not eliminate observed pattern segregation, the Department will suspend paving, even if it is before the Contractor places the entire test section. Propose additional corrective actions, and construct another test section. Resume normal paving operations after constructing an entire test section without pattern segregation as determined by the Representative.

3.c Defective Pavement. At locations selected by the Inspector and with the Inspector present, drill a minimum of three 6-inch diameter cores from the area of pattern segregation and a minimum of three cores from the pavement representing a non-segregated area. Do not compress, bend, or distort samples during cutting and handling and immediately provide the cores to the Inspector. The Inspector will transport cores to the producer's laboratory. With the Inspector present, test the cores at the plant for density, asphalt content, and gradation. The Department may request additional tests as part of its evaluation of pattern segregation. Determine the maximum theoretical density according to Bulletin 27, the core density according to PTM No. 715, and asphalt content according to PTM No. 757 if previously identified problematic aggregates are used in the mixture, PTM No. 702 modified Method D, and PTM No. 739 or other test method identified in the producer QC Plan.

An area of pattern segregation contains defective pavement if the summation of absolute deviations from any two sieves is 20% or more from the JMF, the core density is defective, the mixture is defective in asphalt content, or the mixture is defective for percent passing the 75 µm (No. 200) sieve. Remove and replace the full width of the affected lane and a minimum of 5 feet beyond each end of the area with unacceptable pattern segregation. Construct replacement pavement conforming to the appropriate surface tolerances as specified in Section 313.3(l) or Section 413.3(l).

Section 413.3(h)4. Flushing

4. Flushing. Provide a mix that will not flush. Flushing is continuous or repeated areas of excessive asphalt on the pavement surface. The Department may recognize flushing until the Department approves the project through final inspection. The Department will address flushing as follows:

4.a Evaluating Flushing. When the Representative observes flushing, then:

• The Representative will immediately notify the Contractor of the observed flushing.

• The Contractor may continue work at their own risk while immediately and continually adjusting the operation to eliminate flushing from future work.

• In the presence of the Representative, determine the average depth of pavement surface macrotexture according to PTM No. 751 in areas of suspected flushing. If the average texture depth is less than or equal to 0.006 inches, then the pavement will be considered to be flushed and is defective.

4.b Test Section. If the macrotexture tests identify flushing, then:

• Immediately suspend placing the paving course. Evaluate the cause of flushing according to the Paving Operation QC Plan and as directed. Provide proposed corrective actions to the Representative and do not resume placing the paving course until after the Representative reviews the proposed corrective actions and authorizes paving to continue.

• Remove and replace the defective wearing course at no additional cost to the Department for the full width of the affected lane and a minimum of 5 feet beyond each end of the area of defective wearing course. Construct replacement wearing course conforming to the appropriate surface tolerances as specified in Section 413.3(l).

• After the Representative allows paving to resume, place a test section not to exceed 200 tons. If the corrective actions do not eliminate observed flushing, the Department will suspend paving even if it is before the Contractor places the entire test section. Propose additional corrective actions and construct another test section. Resume normal paving operations after constructing an entire test section without flushing as determined by the Representative.

Q12 response: Comparison of the average depth of surface macrotexture between areas with pattern segregation and areas with non-segregated pavement according to PTM No. 751 (http://www.dot.state.pa.us/public/PubsForms/Publications/PUB_19/Pub%2019%20Ch%2011.pdf). The pattern segregation is unacceptable if the difference in average pavement texture depth between the non-segregated and segregated areas exceeds 0.024 inch. The difference of 0.024 inch is used for all pavement types (wearing, binder, & base courses).

Commonwealth of Pennsylvania | PA Test Method No. 751
Department of Transportation | October 2013
10 Pages

LABORATORY TESTING SECTION
Method of Test for
MEASURING SURFACE MACROTEXTURE DEPTH
USING A VOLUMETRIC TECHNIQUE
AND DETERMINING PATTERN SEGREGATION

1. SCOPE

1.1 This method of test, which is a modification of ASTM E965, outlines the procedure for determining the average depth of a pavement surface macrotexture by careful application of a known volume of material on the pavement surface and subsequent measurement of the total area covered. This technique is designed to provide an average depth value of only the pavement macrotexture and is considered insensitive to pavement microtexture characteristics. This method of test is also used to determine pattern segregation in bituminous concrete pavements.

NOTE 1- Pavement macrotexture is defined as the deviations of a pavement surface from a true planar surface. Average texture depth is the average depth between the bottom of the pavement surface voids and the tops of the surface aggregate particles. This test method is considered insensitive to distinguishing between (+) and (-) deviations of a pavement surface from a true planar surface.

NOTE 2- The pavement surface to be measured using this test method must be dry and free of any construction residue, surface debris, and loose aggregate particles that would be displaced or removed during normal environmental and traffic conditions.

2. APPARATUS AND MATERIAL

2.1 Scale- A standard 300-millimeter (12-inch) scale having 2.0 millimeter (0.1 inch) divisions.

2.2 Sample Container- A cylindrical plastic or metal container with an internal volume of approximately 20,000 cubic millimeters (1.2 cubic inches) used to determine the volume of material to be spread on the pavement surface. An 18 mL polyethylene vial with a friction fit snap closure (Fisher Cat. #03-388-E) is suitable and is the standard container used to develop Table 1 in Section 4.

2.3 Spreader Tool- A #14 solid rubber stopper (Fisher Cat. #14-130V) or an ice hockey puck is suitable

2.4 Brushes- Any size of paint brush with a soft bristle is suitable for cleaning loose debris and aggregate particles away from the test locations.

NOTE 3- If it is necessary to test locations that are contaminated with dried mud or other tightly adhering foreign material, a stiff wire brush shall be used to thoroughly clean the area prior to testing.

2.5 Material Storage Container- A one (1) liter (1-quart) plastic sample bottle with a lid is suitable for storing, transporting, and maintaining dry testing material. The container shall be kept sealed except for filling sample containers and recharging.

2.6 Material- Either of the following dry, clean materials is suitable.

NOTE 4- Use the same material for testing each area when conducting pattern segregation tests.

2.6.1 Solid glass beads- Tested by ASTM Test Method D1155 (70% roundness). The beads shall be graded such that 100% of the sample passes a 1.18 mm (No. 16) sieve, and no more than 5% of the sample passes the 150 µm (No. 100) sieve.

2.6.2 Standard graded sand- Meeting the requirements of ASTM Specification C778, Table 1.

2.7 Wind Screen- Any suitable method may be used to prevent turbulence from disturbing the material during the test. A 330 millimeter (13-inch) tubeless tire is the minimum sized tire that is suitable to be used as a shield. This tire is to be placed on the pavement surface around the test site when sufficiently windy conditions prevail or turbulence is created by traffic such that the test procedure is disturbed without the shield.

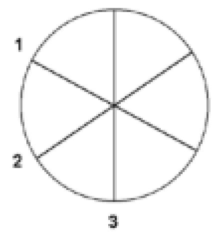
3. PROCEDURE

3.1 Test Surface- Inspect the pavement surface to be measured and select a dry, homogeneous area that contains no unique, localized features such as cracks or joints. Thoroughly clean the pavement surface using a soft bristle brush to remove any residue, debris, or loosely bonded aggregate particles that are on the surface (See NOTES 2 and 3). Position the portable windscreen around the surface test area, if necessary.

3.2 Material Sample Preparation- Fill the sample container with dry material and gently tap the base of the cylinder three times on a rigid surface. Add more material to fill the cylinder to the top, and level the cylinder with a straight-edge.

3.3 Test Measurement- Pour the measured volume of material onto a clean test surface within the area protected by the windscreen. Carefully spread the material in a circular patch with the spreader tool, filling the surface voids flush with the aggregate particle tips. Measure and record the diameter of the circular area covered by the material using the scale. Perform a minimum of three readings on the circular patch. Determine the radius by dividing the average diameter reading by 2. Record the measurements to the nearest 2.5 millimeters (0.1 inch).

Example of circular patch measurements:



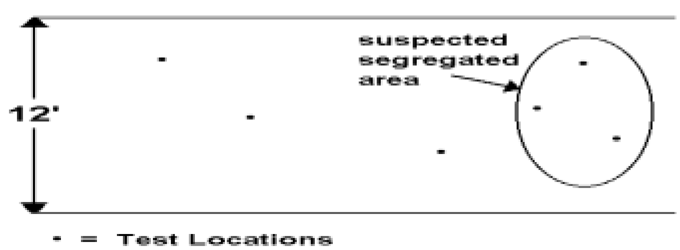
NOTE 5- For very smooth pavement surfaces where test patch diameters exceed 203 millimeters (8-inches), it is recommended that the pavement be re-tested using a smaller sample container. (A 12 mL polyethylene vial, Fisher Cat. #03-388C, with an actual volume of 14 000 mm3 is suitable for such cases).

NOTE 6- For coarse open pavements, it may be necessary to use two or more 18 mL polyethylene vials.

3.4 Number of Test Measurements for Determining Surface Macrotexture when Used to Evaluate Surface Frictional Characteristics- The same operator shall perform at least 5 randomly selected measurements, utilizing PTM No. 1, per lane kilometer (mile) of a given test pavement surface type. Measurements shall be determined in either the right or left wheel path for each longitudinal offset calculated.

3.5 Number of Test Measurements for Determining Pattern Segregation- Perform a minimum of three tests in the suspected segregated area. Perform an equal number of tests in an acceptable area using PTM No. 1. Calculate the average radius for each area, suspected and acceptable. Determine the average texture depth for each area in accordance with Section 4. Calculate the difference between the average texture depths of suspected and acceptable areas to determine pattern segregation.

Example:



4. CALCULATION

4.1 When using a standard sample container (18 mL Fisher vial), refer to the Table 1 Conversion Table, and convert each radius measurement to an average Texture Depth (T.D). Calculate and record an Average Surface Macrotexture Depth (ASMD) to 0.0254 mm (0.001 in.), and a Standard Deviation (S) for the measurements for each pavement surface type. Use Table 2 for the two 18 mL polyethylene vials. When more than two 18 mL polyethylene vials are used, follow the calculation procedure listed in Section 4.2.

4.1.1 Calculate the ASMD by:

4.1.2 Calculate the S by:

Where:
S= Standard deviation

n = Number of measurements
X = ASMD
Xi= Individual T.D. measurement
∑ n i=1 = Sum of the squares of the deviation from ASMD

4.2 When using a container other than the standard sample container, use the following procedure:

4.2.1 Cylinder Volume- Calculate the internal volume of the sample cylinder as follows: 4 d h V = 2 π

Where:
V = Internal cylinder volume, mm3 (in3)
d = Internal cylinder diameter, mm(in.)
h = Cylinder height, mm (in.)

4.2.2 Average Texture Depth - Calculate the average Texture Depth (T.D.) using the following equation: R V T.D.= 2 π

Where:
T.D. = average texture depth, mm (in.)
V = sample volume, mm3 (in3)(calculated in Section 4.2.1)
R = average radius of the area covered by the material, mm (in.)

Calculate and record an Average Surface Macrotexture Depth (ASMD) to 0.025 mm (0.001 in.) and a Standard Deviation (S) as shown in Sections 4.1.1 and 4.1.2 for each pavement surface type.

5. REPORT

5.1 The report for each pavement test surface type shall contain the following items:

5.1.1 Date of Testing

5.1.2 Identify the roadway (Co., SR, Seg.) and pavement surface type (seal coat, etc.)

5.1.3 Record each test location (Seg. offset, L or R wheel path) with an average texture depth (T.D.) determined for each location.

5.1.4 For each pavement surface type report the following: Average Surface Macrotexture Depth (ASMD), Range (R) of measurements, and the Standard Deviation (S).

6. REFERENCES

ASTM E965
British Standards - Sand Patch Method

TABLE 1- STANDARD MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius		Texture Depth		Radius		Texture Depth	
mm	(in)	mm	(in)	mm	(in)	mm	(in)
50.8	2.0	2.47	0.097	129.5	5.1	0.380	0.015
53.3	2.1	2.24	0.088	132.1	5.2	0.365	0.014
55.9	2.2	2.04	0.080	134.6	5.3	0.352	0.014
58.4	2.3	1.87	0.073	137.2	5.4	0.338	0.013
61.0	2.4	1.71	0.067	139.7	5.5	0.326	0.013
63.5	2.5	1.58	0.062	142.2	5.6	0.315	0.012
66.0	2.6	1.46	0.057	144.8	5.7	0.304	0.012
68.6	2.7	1.35	0.053	147.3	5.8	0.294	0.012
71.1	2.8	1.26	0.050	149.9	5.9	0.283	0.011
73.7	2.9	1.17	0.046	152.4	6.0	0.274	0.011
76.2	3.0	1.10	0.043	154.9	6.1	0.265	0.010
78.7	3.1	1.03	0.040	157.5	6.2	0.257	0.010
81.3	3.2	0.964	0.038	160.0	6.3	0.249	0.010
83.8	3.3	0.907	0.036	162.6	6.4	0.241	0.009
86.4	3.4	0.853	0.034	165.1	6.5	0.234	0.009
88.9	3.5	0.806	0.032	167.6	6.6	0.227	0.009
91.4	3.6	0.762	0.030	170.2	6.7	0.220	0.009
94.0	3.7	0.721	0.028	172.7	6.8	0.214	0.008
96.5	3.8	0.684	0.027	175.3	6.9	0.207	0.008
99.1	3.9	0.649	0.026	177.8	7.0	0.201	0.008
101.6	4.0	0.617	0.024	180.3	7.1	0.196	0.008
104.1	4.1	0.588	0.023	182.9	7.2	0.190	0.007
106.7	4.2	0.559	0.022	185.4	7.3	0.185	0.007
109.2	4.3	0.534	0.021	188.0	7.4	0.180	0.007
111.8	4.4	0.510	0.020	190.5	7.5	0.176	0.007
114.3	4.5	0.488	0.019	193.0	7.6	0.171	0.007
116.8	4.6	0.467	0.018	195.6	7.7	0.166	0.007
119.4	4.7	0.447	0.018	198.1	7.8	0.162	0.006
121.9	4.8	0.429	0.017	200.7	7.9	0.158	0.006
124.5	4.9	0.411	0.016	203.2	8.0	0.154	0.006
127.0	5.0	0.395	0.016				

* Valid only when using ONE standard container as specified in Section 2.2 (18 ml vial, Fisher Cat. # 03-388-E, with an actual volume of 20,000 mm^3) or an equivalent container with a measured volume of 20,000 mm^3 (1.2204 in^3).

TABLE 2 - COARSE MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius mm	Radius (in)	Texture Depth mm	Texture Depth (in)	Radius mm	Radius (in)	Texture Depth mm	Texture Depth (in)
50.8	2.0	4.94	0.194	129.5	5.1	0.760	0.030
53.3	2.1	4.48	0.176	132.1	5.2	0.730	0.029
55.9	2.2	4.08	0.161	134.6	5.3	0.703	0.028
58.4	2.3	3.74	0.147	137.2	5.4	0.677	0.027
61.0	2.4	3.42	0.135	139.7	5.5	0.653	0.026
63.5	2.5	3.16	0.124	142.2	5.6	0.630	0.025
66.0	2.6	2.92	0.115	144.8	5.7	0.608	0.024
68.6	2.7	2.71	0.107	147.3	5.8	0.587	0.023
71.1	2.8	2.52	0.099	149.9	5.9	0.567	0.022
73.7	2.9	2.35	0.092	152.4	6.0	0.548	0.022
76.2	3.0	2.19	0.086	154.9	6.1	0.531	0.021
78.7	3.1	2.06	0.081	157.5	6.2	0.514	0.020
81.3	3.2	1.927	0.076	160.0	6.3	0.498	0.020
83.8	3.3	1.814	0.071	162.6	6.4	0.482	0.019
86.4	3.4	1.706	0.067	165.1	6.5	0.467	0.018
88.9	3.5	1.612	0.063	167.6	6.6	0.454	0.018
91.4	3.6	1.525	0.060	170.2	6.7	0.440	0.017
94.0	3.7	1.442	0.057	172.7	6.8	0.427	0.017
96.5	3.8	1.368	0.054	175.3	6.9	0.415	0.016
99.1	3.9	1.297	0.051	177.8	7.0	0.403	0.016
101.6	4.0	1.234	0.049	180.3	7.1	0.392	0.015
104.1	4.1	1.176	0.046	182.9	7.2	0.381	0.015
106.7	4.2	1.119	0.044	185.4	7.3	0.371	0.015
109.2	4.3	1.068	0.042	188.0	7.4	0.360	0.014
111.8	4.4	1.019	0.040	190.5	7.5	0.351	0.014
114.3	4.5	0.975	0.038	193.0	7.6	0.342	0.013
116.8	4.6	0.934	0.037	195.6	7.7	0.333	0.013
119.4	4.7	0.894	0.035	198.1	7.8	0.325	0.013
121.9	4.8	0.857	0.034	200.7	7.9	0.316	0.012
124.5	4.9	0.822	0.032	203.2	8.0	0.309	0.012
127.0	5.0	0.790	0.031				

* Valid only when using TWO standard containers as specified in Section 2.2 (Two 18 mL vials Fisher Cat. #03-388-E with an actual total volume of 40 000 mm^3) or an equivalent container with a measured volume of 40 000 mm^3 (2.4408 in^3).

TABLE 3 - VERY SMOOTH MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius mm	Radius (in)	Texture Depth mm	Texture Depth (in)	Radius mm	Radius (in)	Texture Depth mm	Texture Depth (in)
50.8	2.0	1.73	0.068	129.5	5.1	0.266	0.010
53.3	2.1	1.57	0.062	132.1	5.2	0.256	0.010
55.9	2.2	1.43	0.056	134.6	5.3	0.246	0.010
58.4	2.3	1.31	0.051	137.2	5.4	0.237	0.009
61.0	2.4	1.20	0.047	139.7	5.5	0.228	0.009
63.5	2.5	1.11	0.044	142.2	5.6	0.220	0.009
66.0	2.6	1.02	0.040	144.8	5.7	0.213	0.008
68.6	2.7	0.95	0.037	147.3	5.8	0.205	0.008
71.1	2.8	0.88	0.035	149.9	5.9	0.198	0.008
73.7	2.9	0.82	0.032	152.4	6.0	0.192	0.008
76.2	3.0	0.77	0.030	154.9	6.1	0.186	0.007
78.7	3.1	0.72	0.028	157.5	6.2	0.180	0.007
81.3	3.2	0.675	0.027	160.0	6.3	0.174	0.007
83.8	3.3	0.635	0.025	162.6	6.4	0.169	0.007
86.4	3.4	0.597	0.024	165.1	6.5	0.164	0.006
88.9	3.5	0.564	0.022	167.6	6.6	0.159	0.006
91.4	3.6	0.534	0.021	170.2	6.7	0.154	0.006
94.0	3.7	0.505	0.020	172.7	6.8	0.149	0.006
96.5	3.8	0.479	0.019	175.3	6.9	0.145	0.006
99.1	3.9	0.454	0.018	177.8	7.0	0.141	0.006
101.6	4.0	0.432	0.017	180.3	7.1	0.137	0.005
104.1	4.1	0.411	0.016	182.9	7.2	0.133	0.005
106.7	4.2	0.392	0.015	185.4	7.3	0.130	0.005
109.2	4.3	0.374	0.015	188.0	7.4	0.126	0.005
111.8	4.4	0.357	0.014	190.5	7.5	0.123	0.005
114.3	4.5	0.341	0.013	193.0	7.6	0.120	0.005
116.8	4.6	0.327	0.013	195.6	7.7	0.117	0.005
119.4	4.7	0.313	0.012	198.1	7.8	0.114	0.004
121.9	4.8	0.300	0.012	200.7	7.9	0.111	0.004
124.5	4.9	0.288	0.011	203.2	8.0	0.108	0.004
127.0	5.0	0.276	0.011				

* Valid only when using ONE standard container as specified in Section 3.3 (12 mL vial Fisher Cat. #03-388-C with an actual volume 0f 14 000 mm^3) or an equivalent container with a measured volume of 14 000 mm^3 (0.8543 in^3).

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Q13 response: Gradation, asphalt content, and pavement density laboratory tests are used to determine if the pattern segregation is defective and the segregated pavement should be removed and replaced. The specific specification language is: 3.c Defective Pavement. At locations selected by the Inspector and with the Inspector present, drill a minimum of three 6-inch diameter cores from the area of pattern segregation and a minimum of three cores from the pavement representing a non-segregated area. Do not compress, bend, or distort samples during cutting and handling and immediately provide the cores to the Inspector. The Inspector will transport cores to the producer's laboratory. With the Inspector present, test the cores at the plant for density, asphalt content, and gradation. The Department may request additional tests as part of its evaluation of pattern segregation. Determine the maximum theoretical density according to Bulletin 27, the core density according to PTM No. 715, and asphalt content according to PTM No. 757 if previously identified problematic aggregates are used in the mixture, PTM No. 702 modified Method D, and PTM No. 739 or other test method identified in the producer QC Plan. An area of pattern segregation contains defective pavement if the summation of absolute deviations from any two sieves is 20% or more from the JMF, the core density is defective, the mixture is defective in asphalt content, or the mixture is defective for percent passing the 75 µm (No. 200) sieve. Remove and replace the full width of the affected lane and a minimum of 5 feet beyond each end of the area with unacceptable pattern segregation. Construct replacement pavement conforming to the appropriate surface tolerances as specified in Section 313.3(l) or Section 413.3(l). Links/References: PTM Nos. (http://www.dot.state.pa.us/public/PubsForms/Publications/PUB_19/Pub%2019%20Ch%2011.pdf) Reference to Bulletin 27 for maximum theoretical density - Bulletin 27 references AASHTO T 209 with some exceptions to delete some apparatus from use (plastic vacuum bowls, vacuum flask for mass determination in air, plastic pycnometers, and water aspirator), to specify Test Method A - Mechanical Agitation, to revise conditioning time to 2 h +/- 5 min (non-absorptive coarse aggregate - <=1.5% as determined by AASHTO T 85) or to 6 h +/- 5 min (absorptive coarse aggregate - >1.5% as determined by AASHTO T 85), and to revise conditioning temperature by grade of binder (PG58S-28 = 140 +/- 3 C, PG 64S-22 = 145 +/- 3C, and PG64E-22 = 153 +/- 3C).

Saved as pdfs:
PTM No. 702 modified Method D p. 503, 24 pages
PTM No. 715 p. 567-571 5 pages
PTM No. 739 p. 608-612 5 pages
PTM No. 757 p. 677-688 12 pages

5 Pages

LABORATORY TESTING SECTION
Method of Test for
DETERMINATION OF BULK SPECIFIC GRAVITY OF
COMPACTED BITUMINOUS MIXTURES

1. SCOPE
   1.1 This method of test is intended for determining the bulk specific gravity of laboratory compacted bituminous mixtures or bituminous roadway samples, such as cores, small sawed slabs, density ring samples, etc. This method shall not be used if the samples contain open or interconnecting voids and/or absorb more than 3.0 percent water. For such samples, PTM No. 716 shall be used.

2. TEST SPECIMEN
   2.1 Compacted specimens in accordance with PENNDOT Methods or obtained in accordance with PENNDOT methods of sampling a compacted roadway.
   2.2 Size of specimens- It is recommended, (1) that the diameter of cylindrically molded or cored specimens, or the length of the sides of the sawed specimens, be at least equal to four times the nominal maximum size of the aggregate; and (2) that the thickness of the specimens be at least 1.5 times the nominal maximum size of the aggregate.
   2.3 Specimens shall be free of foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.
   2.4 If desired, specimens may be separated from the other pavement layers by sawing or other suitable means. Care shall be exercised to ensure sawing does not damage the specimens.

METHOD A (VOLUMETER)

3. APPARATUS
   3.1 Weighing Device-A weighing device conforming to the requirements of AASHTO M-231, Class G2
   3.2 Water Bath- Thermostatically controlled so as to maintain the bath temperature at 25 ± 0.5ºC (77 ± 0.9ºF)
   3.3 Thermometer- ASTM 17C (17F), having a range of 19 to 27ºC (66 to 80ºF), graduated in 0.1ºC (0.2ºF) subdivisions
   3.4 Volumeter[1] - Calibrated, 1.2 L or an appropriate capacity depending upon the size of the test sample

[1] Aluminum Volumeters of different sizes available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA. 16127 and Rainhart Co., 604 Williams St., Austin, TX, 78765 have been found suitable.

4. PROCEDURE

4.1 Immerse the specimen in the water bath and let saturate for at least 10 minutes. At the end of the 10 minute period, fill a calibrated volumeter with distilled water at 25 ± 1ºC (77 ± 1.8ºF). Place the saturated specimen into the volumeter. Bring the temperature of the water in the volumeter to 25 ± 1ºC (77 ± 1.8ºF), and cover the volumeter making certain that some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and contents to the nearest 0.1 of a gram.

4.2 Remove the immersed and saturated specimen from the volumeter, quickly damp dry the saturated specimen with a damp towel, and as quickly as possible weigh the specimen. Any water that seeps from the specimen during the weighing operation is considered as a part of the saturated specimen. Dry the specimen to constant mass (NOTE 1). Weigh the dried specimen to the nearest 0.1 of a gram.

NOTE 1- Constant mass shall be defined as the mass at which further drying at 52 ± 3ºC (125 ± 5ºF) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at 52 ± 3ºC (125 ± 5ºF), flipped top to bottom, then dried until a Minimum Standard Drying Time of 20 hours has elapsed. This Minimum Standard Drying Time shall be reestablished using the procedure in NOTE 1A if there are substantial changes in ovens, paving materials, or mix design methods from 2002 conditions. Laboratory compacted specimens and density ring samples need not be dried.

NOTE 1A- PROCEDURE FOR DETERMINING A MINIMUM STANDARD DRYING TIME: Assemble a random sample of cores representing the compacted asphalt mixtures typically tested. Saturate the cores with water, and place the saturated cores in the 52 ± 3ºC (125 ± 5ºF) oven overnight. At the start of the following workday flip the cores top to bottom. Continue to dry and weigh the cores at two-hour intervals until constant mass is attained. Document and use the time it took for all cores to reach constant weight as the Minimum Standard Drying Time.

NOTE 2- If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the dry mass of the specimen can be determined. Then the volumeter containing the saturated specimen and water can be weighed. The mass of the saturated specimen can be obtained last.

5. CALCULATIONS

5.1 Calculate the bulk specific gravity (dry basis) of the samples as follows (report the value to three decimal places):

$$\mathrm{GSm} = \frac{\mathrm{WSm}}{\left(0.997\,\frac{\mathrm{g}}{\mathrm{mL}}\right) \mathrm{x}\ [\mathrm{VVo} - \left(1.003\,\frac{\mathrm{mL}}{\mathrm{g}}\right) \mathrm{x} (\mathrm{WT} - \mathrm{WSa} - \mathrm{WVo})]}$$

Where:
GSm = bulk specific gravity of the specimen at 25.0ºC (77ºF)
WSm = mass in grams of the dry specimen
VVo = volume in mL of the volumeter at 25.0ºC (77ºF) to the nearest tenth of a milliliter
WT = total mass in grams of the volumeter, saturated specimen, and water in the volumeter at 25.0ºC (77ºF)
WSa = mass in grams of the saturated specimen
WVo = mass in grams of the volumeter

5.2 Calculate the percent water absorbed by the specimen as follows (report the value to one decimal place):

$$\text{Percent Water Absorbed} = \frac{\mathrm{WSa} - \mathrm{WSm}}{\left(0.997\,\frac{\mathrm{g}}{\mathrm{mL}}\right) \mathrm{x}\ [\mathrm{VVo} - \left(1.003\,\frac{\mathrm{mL}}{\mathrm{g}}\right) \mathrm{x} (\mathrm{WT} - \mathrm{WSa} - \mathrm{WVo})]}\ \mathrm{x}\ 100$$

If the percent water absorbed is more than 3.0 percent, use PTM No. 716.

METHOD B (SUSPENSION IN WATER)

AASHTO T-166, Method A, except as follows:

NOTE 1- replace with the following: Constant mass shall be defined as the mass at which further drying at 52 ± 3ºC (125 ± 5ºF) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at 52 ± 3ºC (125 ± 5ºF), flipped top to bottom, then dried until a Minimum Standard Drying Time of 20 hours has elapsed. This Minimum Standard Drying Time shall be reestablished using the procedure in NOTE 1A if there are substantial changes in ovens, paving materials, or mix design methods from 2002 conditions. Laboratory compacted specimens and density ring samples need not be dried.

Add: NOTE 4 – Referee Method- In case of discrepancies between the test results obtained by Method A and Method B, the referee test shall be Method A.

METHOD C (RAPID TEST)

AASHTO T-166, Method C

South Carolina

Q7 response: 2007 Standard Specification - 401.4.28Defined as areas of non-uniform distribution of coarse and fine aggregate particles in a compacted HMA pavement.

401.4.28 Segregation Identification and Correction

1 401.4.28 Segregation is defined as areas of non-uniform distribution of coarse and fine aggregate particles in a compacted HMA pavement.

2 401.4.28 Conduct necessary production, storage, loading, placing, and handling procedures to prevent segregation. Prevent placement of a segregated HMA mat by making plant modifications or providing auxiliary equipment.

4 401.4.28 Correct segregated areas in HMA courses at no additional expense to the Department. Meet all compaction and rideability requirements on roads with corrected segregated areas.

5 401.4.28 Correct segregated HMA courses that are not considered riding courses by removing and replacing segregated areas for the full depth of the course and extend at least 10 feet on either side of the segregated areas for the full width of the paving lane.

6 401.4.28 Correct all segregated HMA riding courses and segregated courses placed immediately below open graded friction courses by removing and replacing these segregated areas for the full depth of the riding course and extend at least 300 feet on either side of the segregated areas.

7 401.4.28 Overlay the entire roadway with an open grade friction course when more than 25% of the final roadway surface area is corrected due to segregation. Place the open graded friction course at no additional expense to the Department.

8 401.4.28 Meet all compaction and rideability requirements on roads with corrected segregated areas.

Texas

Q12 response: Segregation (density profile) - Tex-207-F, Part V. Our specification requires this method for all layers of HMA. Test Procedure - https://ftp.txdot.gov/pub/txdot-info/cst/TMS/200-F_series/pdfs/bit207.pdf See Specification SS3077 - http://www.dot.state.tx.us/apps-cg/specs/ShowAll.asp?year=4&type=SS&number=3

Q21 response mentions same documents: Test procedure - Tex-207-F, Part V: https://ftp.txdot.gov/pub/txdot-info/cst/TMS/200-F_series/pdfs/bit207.pdf Specification-SS3077: http://www.dot.state.tx.us/apps-cg/specs/ShowAll.asp?year=4&type=SS&number=3 Within our specification, we have an entire section on segregation density profiles. Perform Ctrl+f to search for "segregation".

Test Procedure for

DETERMINING DENSITY OF COMPACTED BITUMINOUS MIXTURES

TxDOT Designation: Tex-207-F

Effective Date: January 2020

1. SCOPE

1.1 This test method determines the bulk specific gravity (G_a) of compacted bituminous mixture specimens. Use the G_a of the specimens to calculate the degree of densification or percent compaction of the bituminous mixture.

1.2 Refer to Table 1 for Superpave and conventional mix nomenclature equivalents. Replace conventional nomenclature with the Superpave nomenclature when required.

Table 1
Nomenclatures and Definitions

Nomenclatures		Definitions
Conventional	Superpave	
AC	-	Asphalt Content
A_g	P_s	Percent by weight of aggregate in the mixture
A_s	P_b	Percent by weight of asphalt binder in the mixture
G_a	G_{mb}	Bulk specific gravity of compacted specimens
G_e	G_{se}	Effective specific gravity of the combined aggregates
G_r	G_{mm}	Theoretical maximum specific gravity
G_{rc}	G_{mm}	Theoretical maximum specific gravity corrected for water absorption during test
G_s	G_b	Specific gravity of the asphalt binder determined at 77°F (25°C)
G_t	$G_{max\text{-}theo}$	Calculated theoretical maximum specific gravity of the mixture at the specified AC

1.3 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. DEFINITIONS

2.1 *Bulk Specific Gravity (G_a)*—the ratio of the weight of the compacted bituminous mixture specimen to the bulk volume of the specimen.

2.2 *Percent Density* or *Percent Compaction*—the ratio of the actual G_a of the compacted bituminous mixture specimen to the theoretical maximum specific gravity of the combined aggregate and asphalt contained in the specimen expressed as a percentage.

PART I—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES

3. SCOPE

3.1 Use this procedure for all compacted bituminous mixtures, except use Part VI for mixtures with more than 2.0% water absorption.

4. APPARATUS

4.1 *Balance*, Class G2 in accordance with Tex-901-K, minimum capacity of 10,000 g, equipped with suitable apparatus to permit weighing the specimen while suspended in water.

4.2 *Suspension Apparatus, Non-Absorptive String, Metal Bucket, or a Cage*, attached to the balance with a metal wire or a non-absorptive string.

4.3 *Mercury Thermometer*, marked in 2°F (1°C) divisions or less, or digital thermometer, capable of measuring the temperature specified in the test procedure.

4.4 *Water Bath with a Tank Heater and Circulator*, for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level.

4.5 *Towel*, suitable for surface drying the specimen.

4.6 *Vacuum Device*, such as Coredryer (optional).

4.7 *Measuring Device*, such as a ruler, calipers, or measuring tape.

4.8 *Drying Oven*, capable of attaining the temperature specified in the test procedure.

5. TEST SPECIMENS

5.1 Test specimens may be laboratory-molded mixtures or pavement cores.

5.2 Avoid distorting, bending, or cracking the specimens during and after removal from pavements or molds. Store the specimens in a cool place.

5.3 Obtain cores in accordance with Tex-251-F, Part I.

5.4 Laboratory-Molded Specimens:

5.4.1 Measure and record the specimen height to the nearest 1/16 in.

5.5 Pavement Cores

5.5.1 Prepare pavement cores for testing in accordance with Tex-251-F, Part II.

6. PROCEDURES

6.1 For specimens containing moisture, follow the instructions in Sections 6.2–6.9. For laboratory-molded specimens, perform the instructions in Sections 6.3–6.9.

6.2 Place the specimen in an oven with the flat side of the specimen on a flat surface to complete the drying process. Oven-dry the specimen for a minimum of two hr. at a temperature of 115 ± 5°F (46 ± 3°C) to constant weight. “Constant weight” is the weight at which further oven drying does not alter the weight by more than 0.05% in a two hr. or longer drying interval when calculated in accordance with Section 7.1.

Note 1—The oven drying temperature can be reduced to a temperature no lower than 100°F (38°C) provided that the specimen remains in the oven for a minimum of eight hr.

Note 2—As an option, for specimens not subject to further testing and evaluation, rapid dry in an oven at a temperature of 140°F (60°C), for a maximum of 12 hr. to constant weight.

Note 3—As an option, use a Coredryer in conjunction with or instead of a drying oven. Dry all samples to a constant weight as defined in Section 6.2.

6.3 Allow the specimen to cool, and then weigh in air to the nearest 0.1 g.

6.4 Record and designate this weight as A in Section 7.2.

6.5 Unplug or turn off the water circulator in the water bath while obtaining the submerged sample weight. Attach the suspension apparatus to the scale and submerge in water. Tare the scale with the suspension apparatus submerged in water.

6.6 Immerse the specimen in a water bath at 77 ± 3°F (25 ± 2°C).

6.7 Leave the sample in the water for three min. ± 15 sec. When the scale readings stabilize, record the specimen weight and designate as C in Section 7.2.

6.8 Remove the specimen from water. Dry the surface of the specimen by blotting gently with a damp towel for no longer than 20 sec. To facilitate drying, gently rotate the specimen while blotting, if necessary; however do not shake, sling, or perform any action that removes water from within the specimen.

6.9 Weigh the specimen in air. Record as the saturated surface dry weight (SSD) and designate as B in Section 7.2.

7. CALCULATIONS

7.1 Calculate the percent difference in weight:

$$PercentDifference = (\frac{InitialWeight - FinalWeight}{InitialWeight})$$

7.2 Calculate G_a and percent of water absorbed by the specimen:

$$G_a = \frac{A}{B - C}$$

Where:
G_a = bulk specific gravity,
A = weight of dry specimen in air, g,
B = weight of the SSD specimen in air, g, and
C = weight of the specimen in water, g.

Note 4—If the percent absorption exceeds 2.0%, use Part VI.

PART II—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING PARAFFIN

8. SCOPE

8.1 The paraffin method is no longer an accepted process.

8.2 Refer to Part VI of this test procedure for absorptive mixtures (those with more than 2.0% water absorption).

9. SCOPE

9.1 Use this procedure to determine the in-place density of compacted bituminous mixtures using a nuclear density gauge.

10. APPARATUS

10.1 *Nuclear Density Gauge*.
10.2 *Portable Reference Standard*.
10.3 *Calibration Curves for the Nuclear Gauge*.
10.4 *Scraper Plate and Drill Rod Guide*.
10.5 *Drill Rod and Driver or Hammer*.
10.6 *Shovel, Sieve, Trowel, or Straightedge and Miscellaneous Hand Tools*.
10.7 *Gauge Logbook*.

11. STANDARDIZATION

11.1 To standardize the nuclear density gauge, turn on the apparatus and allow it to stabilize.

Note 5—Follow the manufacturer's recommendations to ascertain the most stable and consistent results.

11.2 Perform standardization with the apparatus located at least 25 ft. (8 m) away from other sources of radioactivity. Clear the area of large masses or other items that may affect the reference count rate.

Note 6—The preferred location for standardization checking is the pavement location tested. This is the best method for determining day-to-day variability in the equipment.

11.3 Take a minimum of four repetitive readings using Table 2 at the normal measurement period, and determine the average of these readings.

Note 7—One measurement period of four or more times the normal period is acceptable if available on the apparatus. This constitutes one standardization check.

11.4 Detect the total number of gammas during the period by determining the count per measurement period. Correct the displayed value for any prescaling built into the instrument. Record this corrected value as Ns.

Note 8—The prescale value (F) is a divisor, which reduces the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.

11.5 Use the value of Ns to determine the count ratios for the current day's use of the instrument.

Note 9—Perform another standardization check if for any reason the measured density becomes suspect during the day's use.

11.6 Table 2 lists the required actions to take based on the results from Section 11.3

Table 2
Reference Standard

If . . .	Then. . .
the value obtained is within the limits stated in limits calculation	the apparatus is considered to be in satisfactory operating condition and the value may be used to determine the count ratios for the day of use.
the value is outside these limits	allow additional time for the apparatus to stabilize, make sure the area is clear of sources of interference, then conduct another standardization check.
the second standardization check is within the limits	the apparatus may be used.
the second standardization check also fails the test	the apparatus must be adjusted or repaired as recommended by the manufacturer.

12. CALCULATIONS

12.1 Use the test results from Section 11.3 and the following calculations to determine the limit:

$$(N_s - N_o) \leq 2.0\sqrt{N_o/F}$$

Where:
N_s = value of current standardization count
N_o = average of the past four values of Ns taken previously
F = value of any prescale.

13. PROCEDURE

13.1 To determine the in-place density using a nuclear density gauge, select an area that is relatively free of loose material, voids, or depressions. Avoid elevating the gauge above the surface of the material to be tested. Note 10—Select an area at least 12 in. (0.3 m) away from surface obstructions such as curbing, etc. It is optional to use fine sand to fill any voids or minor depressions.

13.2 Measure the density of the selected area in either the backscatter or direct transmission mode. Note 11—The direct transmission method is only applicable for lifts greater than two in. (50 mm) thick.

13.3 Follow the instructions in Sections 13.3.1–13.3.2 to measure the in-place density of compacted bituminous pavements using a nuclear density gauge in the backscatter mode.
13.3.1 Firmly seat the density gauge on the selected area so it is in full contact with the surface.
13.3.2 Record the readings that are required at each location with the probe in the backscatter position. Do not leave the gauge in one position on the compacted bituminous pavement for a long time, as erratic readings may result from the hot surface. Proceed to Section 13.5.
13.4 Follow the instructions in Sections 13.4.1–13.4.4 to measure the in-place density of compacted bituminous pavements using a nuclear density gauge in the direct transmission mode.
13.4.1 Make a hole two in. (50 mm) deeper than the transmission depth used with the drive pin and guide plate.

Note 12—The hole must be as close as possible to 90° from the plane surface.

13.4.2 Firmly seat the density gauge on the prepared area so it is in full contact with the surface.
13.4.3 Adjust the probe to the desired transmission depth. Pull the gauge so that the probe is in contact with the side of the hole nearest the detector tubes.
13.4.4 Measure and record the readings required for each location for the particular type of gauge used. Proceed to Section 13.5.
13.5 Use one of the following methods to determine the in-place density.
13.5.1 Divide the field counts by the standard counts.

OR

13.5.2 Use the appropriate calibration curves, if necessary.

Note 13—Most models are now programmable to provide direct reading of the nuclear density or percent compaction.

13.6 Take cores or sections of the pavement from the same area selected for the nuclear tests when correlating the nuclear density to the actual density of the compacted material.
13.7 Measure the G_a of the cores or samples taken from the selected area tested for density as described in Part I or Part VI. Establish a correlation factor using a minimum of seven core densities and seven nuclear densities. Adjust the nuclear density readings using this correlation factor to correlate with the actual Ga determined through laboratory testing.

Note 14—When testing thin lifts in the backscatter mode, the influence of underlying strata with varying densities may render this procedure impractical without special planning. Most manuals for the nuclear gauge describe the various methods to use with thin lifts.

13.8 Make correlations as described in Section 13.6 and compare the correlated nuclear density to the G_r or G_{rc} of the mixture when controlling in-place density with the nuclear gauge. Calculate the percent density or directly read from programmable models to determine air-void content.

PART IV—ESTABLISHING ROLLER PATTERNS (CONTROL STRIP METHOD)

14. SCOPE

14.1 Use this procedure to establish roller patterns for bituminous pavement.

15. APPARATUS

15.1 *Nuclear Density Gauge*.
15.2 *Electrical Impedance (Nonnuclear) Density Measurement Gauge* (Optional).
15.3 *Portable Reference Standard*.
15.4 *Calibration Curves for the Nuclear Gauge*.
15.5 *Scraper Plate and Drill Rod Guide*.
15.6 *Drill Rod and Driver or Hammer*.
15.7 *Shovel, Sieve, Trowel, or Straightedge and Miscellaneous Hand Tools*.
15.8 *Gauge Logbook*.

16. PROCEDURE

16.1 To establish roller patterns (control strip method), refer to the gauge manufacturer's instructions for operating the density gauge.

Note 15—Standardize the equipment at the start of each day's use as described in Part III when using a nuclear density gauge.

Note 16—Operate electrical impedance (nonnuclear) gauges in continuous mode to ensure all data is from the location in question.

16.2 Establish a control strip approximately 300 ft. (90 m) long and at least 12 ft. (3.5 m) wide or the width of the paving machine. Select three test sites.

Note 17—Avoid areas near edges or overlap of successive passes of the rollers.

16.3 Allow the roller to complete a minimum of two coverages of the entire control strip before checking the density. Perform density tests at the three test sites selected. Record the results. Mark each test site very carefully so that subsequent tests made are in the same position and location. Use a colored marker keel to outline the gauge before taking the readings. Take the tests as quickly as possible and release rollers to complete additional coverage to prevent cooling of unrolled areas.

16.4 Repeat the density tests at the previously marked test sites. Continue this process of rolling and testing until there is no significant increase in density. Try several different combinations of equipment, and numbers of passes with each combination, to determine the most effective rolling pattern.

Note 18—In-place density determined with roadway cores is the final measure of rolling pattern effectiveness.

16.5 Construct another section, without interruption, using the roller patterns and number of coverages determined by the control strip after completion of the control strip tests. Take random density tests on this section to verify the results from the control strip.

Note 19—It may be possible to reduce the required coverages based on these tests.

16.6 Make density tests for job control in accordance with the Guide Schedule of Sampling and Testing or as often as necessary, when some changes in the compacted material indicate the need.

17. NOTES

17.1 Visual observation of the surface being compacted is a very important part of this procedure. Cease rolling and get an evaluation of the roller pattern if obvious signs of distress develop, such as cracking, shoving, etc. Structural failures due to over-compaction will cause the density tests to indicate the need for more compaction. Observe closely and take particular care when using vibratory rollers, since they are more likely to produce over-compaction in the material.

17.2 Use the minimum test time allowed by the particular gauge when measuring density on hot material, since the gauge may display erratic results if overheated.

17.3 Exercise particular care to clean the bottom of the gauge after using it on asphalt pavement.

17.4 Use the correlation procedures outlined in Part III, Section 13.7 when using specified density and rolling patterns with a nuclear density gauge.

17.5 This procedure provides a general guide to establish roller patterns. Follow the manufacturer's instruction manual furnished with the particular density gauge for specific operation of that gauge. This is essential, since several different models and different brands are in standard use by the Department.

17.6 Nuclear gauges and the user of the nuclear gauges must meet all requirements of the Department's radioactive material license, "Nuclear Gauge Operating Procedures," and the *Texas Rules for Control of Radiation*.

PART V—DETERMINING MAT SEGREGATION USING A DENSITY-TESTING GAUGE

18. SCOPE

18.1 Use this procedure to identify segregation in bituminous pavements after placement on the roadway using a density-testing gauge.

19. APPARATUS

19.1 *Nuclear Density Gauge*.
19.2 *Thin Lift Density Gauge* (Optional).
19.3 *Electrical Impedance (Nonnuclear) Measurement Gauge* (Optional).
19.4 *Measuring Tape* (Optional).

20. REPORT FORMS
20.1 Use Segregation Density Profile Form to identify segregation in a pavement section.

21. PROCEDURE
21.1 Refer to the manufacturer's instructions for operating the density gauge.

Note 20—It is not necessary to calibrate the gauge to the mix.

Note 21—Operate electrical impedance (nonnuclear) gauges in continuous mode to ensure all data is from the location in question.

21.2 Profile a 50 ft. (15 m) section of the bituminous pavement.
21.3 When profiling a location where the paver stopped for more than 60 sec., perform the instructions in Sections 21.3.1–21.3.3.
21.3.1 Identify the location where the paver stopped paving, such as sporadic mix delivery.
21.3.2 Move approximately 10 ft. (3 m) behind the location where the paver stopped paving, and mark and record this location as the beginning of the profile section.
21.3.3 Proceed to Section 21.6.
21.4 When profiling a random location, randomly select an area, and then choose an area with visible segregation, if possible. Proceed to Section 21.6.
21.5 When profiling an area with segregation of longitudinal streaking greater than the profile length, perform the instructions in Sections 21.5.1–21.5.5.
21.5.1 Profile the area at an angle in a diagonal direction.
21.5.2 Start the profile with a transverse offset of 2 ft. (0.6 m) from the center of the longitudinal streak.
21.5.3 End profile with a transverse offset of 2 ft. (0.6 m) on the opposite side of the longitudinal streak.
21.5.4 Do not start or end a profile less than 1 ft. (0.3 m) from the pavement edge.
21.5.5 Proceed to Section 21.7.
21.6 Determine the transverse offset 2 ft. (0.6 m) or more from the pavement edge. Take density readings in a longitudinal direction and do not vary from this line. Visually observe the mat and note the surface texture in the section and the location of any visible segregated areas. Take additional readings along the transverse offset in areas with visible segregation. Include any visually segregated areas in the profile.
21.7 After completion of the final rolling patterns, position the density gauge at the identified location.
21.7.1 *Use of a Nuclear Density Gauge*:
21.7.1.1 Take three one min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge at each random sample location.
21.7.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.
21.7.2 *Use of an Electrical Impedance Gauge*:
21.7.2.1 Take two readings; it is not necessary to move the gauge between readings.

Note 22—Operate electrical impedance (nonnuclear) gauges in continuous mode to ensure all data is from the location in question.

21.8 Record the in-place density gauge readings.
21.9 Average the readings before moving the density gauge. Compare each individual reading to the average. Discard any single readings that vary more than 1 pcf (16 kg/m^3) from the average. Take additional readings to replace the discarded readings until all the readings are within 1 pcf (16 kg/m^3) of the average.

21.10 Move the density gauge approximately 5 ft. (1.5 m) forward in the direction of the paving operation. Take an additional set of readings at any location with visible segregation in between the 5 ft. (1.5 m) distance.

21.11 Repeat the instructions in Sections 21.7–21.10. Complete a minimum of 10 sets of readings.

Note 23—Use a nuclear density gauge to verify impedance gauge readings whenever readings from an impedance gauge may not be accurate.

21.12 Determine the average density from all locations.

21.13 Determine the difference between the highest and lowest average density.

21.14 Determine the difference between the average and lowest average density.

21.15 Record the data using the Example Segregation Profile Worksheet.

PART VI—BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING THE VACUUM METHOD

22. SCOPE

22.1 Use this procedure to determine the Ga of compacted bituminous mixtures using the vacuum device. This procedure is applicable for mixtures with more than 2.0% water absorption.

23. APPARATUS

23.1 *Specialized Vacuum Sealing Device*.

23.2 *Balance*, Class G2 in accordance with Tex-901-K, minimum capacity of 10,000 g, equipped with suitable apparatus to permit weighing of the specimen while suspended in water.

23.3 *Suspension Apparatus, Non-Absorptive String, Metal Bucket, or Cage*, attached to the balance with a metal wire or a non-absorptive string.

23.4 *Mercury Thermometer*, marked in 2°F (1°C) divisions or less, or digital thermometer, capable of measuring the temperature specified in the test procedure.

23.5 *Water Bath with a Tank Heater and Circulator*, for immersing the specimen in water while suspended from a scale, equipped with an overflow outlet for maintaining a constant water level.

23.6 *Vacuum Device*, such as Coredryer (optional).

23.7 *Measuring Device*, such as a ruler, calipers, or measuring tape.

24. TEST SPECIMENS

24.1 Test specimens may be laboratory-molded mixtures or pavement cores.

24.2 Avoid distorting, bending or cracking the specimens during and after removal from pavements or molds. Store the specimens in a cool place.

24.3 Obtain cores in accordance with Tex-251-F, Part I.

24.4 Laboratory-Molded Specimens:

24.4.1 Measure and record the specimen height to the nearest 1/16 in.

24.5 Pavement Cores:

24.5.1 Prepare pavement cores for testing in accordance with Tex-251-F, Part II.

25. MATERIALS

25.1 Use a supply of large and small-specialized polymer bags as recommended by the manufacturer.

26. PROCEDURES

26.1 Vacuum Sealing Device Setup:

26.1.1 Set the vacuum timer.

Note 24—The manufacturer calibrates the vacuum pump timer setting and exhaust at the factory to eliminate drift and variability due to the sealing process. The vacuum pump operates for approximately one min. Contact the manufacturer for adjustments if the vacuum pump stops before this time has elapsed.

26.1.2 Set the sealing bar timer in accordance with the vacuum device manufacturer's recommendations.

Note 25—Inspect the seal quality after the first sealing operation. Reduce the setting if the polymer bag stretches or burns. Increase the setting if the seal is not complete or the bag easily separates.

26.2 *Determine the G_a of Compacted Bituminous Mixtures*:

26.2.1 Perform the instructions in Sections 26.2.2–26.2.3 for specimens containing moisture. Proceed to Section 26.2.4 for laboratory-molded specimens.

26.2.2 Proceed to Section 26.2.3 or, as an option, pre-dry the specimen using a Coredryer or air dry to remove excess moisture.

26.2.3 Place the specimen in an oven with the flat side of the specimen on a flat surface. Oven-dry the specimen for a minimum of two hr. at a temperature of 115 ± 5°F (46 ± 3°C) to a constant weight. "Constant weight" is the weight at which further oven drying does not alter the weight by more than 0.05% in a two hr. or longer drying interval in accordance with Section 7.1. Refer to Part I, Notes 3 and 4.

26.2.4 Allow the specimen to cool to room temperature, and then weigh in air to the nearest 0.1 g. Record and designate this weight as A in Section 27.1.

26.2.5 Open the lid of the vacuum device. Stack or remove rectangular spacer plates in the vacuum chamber of the vacuum device so there is adequate space for the test specimen.

26.2.6 Place a sliding plate in the vacuum chamber on top of the spacer plates away from the seal bar.

Note 26—Place the sliding plate in the chamber to reduce friction during the sealing operation.

26.2.7 Select and use a large or small polymer bag, as recommended by the manufacturer, to seal the specimen.

26.2.8 Weigh the selected polymer bag and record and designate this weight as B in Section 27.1.

26.2.9 Determine the Polymer Bag Correction Factor (CF):

26.2.9.1 Calculate the ratio, R, by dividing the weight of the specimen by the weight of the bag.

26.2.9.2 Use the CF Table provided in the manufacturer's operator guide. 26.2.9.3 Look up the calculated R-value and record and designate the corresponding correction factor from the table as CF in Section 27.1.

26.2.10 Vacuum Seal the Specimens:

26.2.10.1 Place the bag inside the chamber.

26.2.10.2 Place the specimen in the polymer bag, carefully avoiding puncturing or tearing the bag.

26.2.10.3 Center the core in the bag, leaving approximately 1 in. (25.4 mm) of slack on the backside.

26.2.10.4 Position the bag so that approximately 1 in. (25.4 mm) of the open end is evenly against the sealing bar.

26.2.10.5 Close the lid of the vacuum device and hold firmly for two to three sec.

Note 27—The vacuum pump will start, and the lid will stay closed on its own. The vacuum gauge will read less than 28 in. (50 mm) Hg.

26.2.10.6 The lid of the vacuum device will automatically open upon completion of the sealing process. Carefully remove the sealed specimen from the chamber. Gently pull on the polymer bag to ensure the seal is tightly conformed to the specimen. Return to the instructions in Section 26.2.8 if the seal is not tightly conformed to the specimen.

Note 28—A loose seal may be an indication of a leak.

26.2.11 Determine the type of apparatus to use to weigh the samples suspended in water.

26.2.12 Unplug or turn off the water circulator in the water bath while obtaining the submerged sample weight. Attach the apparatus to the scale and submerge in water. Tare the scale with the apparatus submerged in water.

26.2.13 Completely submerge the sealed specimen in water at 77 ± 3°F (25 ± 2°C) and record the weight of the specimen in the bag. Weigh the sealed specimen in water. Record the weight to the nearest 0.1 g when the scale reading stabilizes. Designate this weight as C in Section 27.1.

Note 29—Do not allow the polymer bag to touch the sides of the water bath.

26.2.14 Remove the specimen from the polymer bag and reweigh the specimen in air. Compare this weight to the weight recorded for A in Section 26.2.4. If the difference in weight is greater than 5 g, a leak may have occurred. Dry the sample to a constant weight and repeat the procedure using a new polymer bag.

26.3 Do not use the test results calculated in this test procedure using the vacuum device if this method produces a Ga that is higher than the Ga calculated in Part I. Note 30—Use the results calculated in Part I of this method in this case.

27. CALCULATIONS

27.1 Calculate the G_a of the compacted specimen:

$$G_a = \frac{A}{[(A+B)-C]-\frac{B}{CF}}$$

Where:
G_a = bulk specific gravity,
A = weight of specimen in air, g,
B = weight of the polymer bag in air, g,
C = weight of sealed specimen in water, g, and
CF = correction factor.

PART VII—DETERMINING LONGITUDINAL JOINT DENSITY USING A DENSITYTESTING GAUGE

28. SCOPE

28.1 Use this procedure to perform a longitudinal joint density evaluation on bituminous pavement using a density-testing gauge.

29. APPARATUS

29.1 *Nuclear Density Gauge*.
29.2 *Thin Lift Density Gauge* (Optional).
29.3 *Electrical Impedance (Nonnuclear) Density Measurement Gauge* (Optional).
29.4 *Measuring Tape* (Optional).

30. FORMS

30.1 Longitudinal Joint Density Profile Form.

31. PROCEDURES

31.1 *Perform a Longitudinal Joint Density Using a Density-Testing Gauge*:

31.1.1 Refer to the manufacturer's instructions for operating the density gauge.

31.1.2 Identify the random sample location selected for in-place air void testing. Mark and record this location as the reference point to perform the joint evaluation.

Note 31—This point must be more than 2 ft. (0.6 m) from the pavement edge.

31.1.3 Position the gauge at the random sample location selected for in-place air void testing identified in Section 36.1.2 after completion of the final rolling pattern.

31.1.3.1 *Use of a Nuclear Density Gauge*:

31.1.3.1.1 Take three one min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge.

31.1.3.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.

31.1.3.2 *Use of an Electrical Impedance Gauge*:

31.1.3.2.1 Take two readings; it is not necessary to move the gauge between readings.

Note 32—Operate electrical impedance (nonnuclear) gauges in continuous mode to ensure all data is from the location in question.

31.1.4 Record the density measurements from the density gauge at the random sample location selected for in-place air void testing.

31.1.5 Measure the longitudinal joint density at the right and left edge of the mat, which is or will become a longitudinal joint.

Note 33—Select a location that is perpendicular to the random sample location selected for in-place air void testing. Identify the joint type as "Confined" or "Unconfined."

Note 34—Take additional readings along the longitudinal joint at areas with visible irregularities or segregation.

31.1.6 Position the gauge with the center placed 8 in. (200 mm) from the pavement edge that is or will become a longitudinal joint. Orient the gauge so the longer dimension of the gauge is parallel to the longitudinal joint.

31.1.6.1 *Use of a Nuclear Density Gauge*:

31.1.6.1.1 Take three one min. readings (minimum time length, longer readings can be used) in backscatter mode when using a nuclear density gauge.

31.1.6.1.2 It is optional to use fine sand passing the No. 40 sieve size to fill any voids without elevating the gauge above the rest of the mat.

31.1.6.2 *Use of an Electrical Impedance Gauge*:

31.1.6.2.1 Take two readings; it is not necessary to move the gauge between readings.

Note 35—Operate electrical impedance (nonnuclear) gauges in continuous mode to ensure all data is from the location in question.

31.1.7 Record the density measurements from the density gauge at the longitudinal joint.

31.1.8 Determine the difference in density between the readings taken at the random sample location selected for in-place air void testing and the readings taken at the longitudinal joint.

Note 36—Use a nuclear density gauge to verify impedance gauge readings whenever readings from an impedance gauge may not be accurate.

31.1.9 Record and report the data using the Example Longitudinal Joint Density Worksheet.

31.2 *Determine a Correlated Joint Density*:

31.2.1 Record the average Ga of the cores taken at the random sample location selected for in-place air voids (*A*).

31.2.2 Record the Gr for each sublot evaluated for joint density (*B*).

31.2.3 Record the average density gauge reading in pcf (kg/m^3) at the longitudinal joint sample location for in-place air voids (*C*).

31.2.4 Record the average density gauge reading in pcf (kg/m^3) at the interior mat random sample location for inplace air voids (*D*).

31.2.5 Record and report the data using the Example Longitudinal Joint Density Worksheet.

32. CALCULATIONS

32.1 Calculate the correlated joint density, CJD (%) of the compacted specimen:

$$CJD(\%) = \frac{A}{B} \times \frac{C}{D} \times 100$$

Where:

A = Average G_a of cores at random sample location,

B = Rice gravity, G_r, for each sublot,

C = Average density gauge reading at the longitudinal joint, pcf (kg/m^3), and

D = Average density gauge reading at the interior mat sample location, pcf (kg/m^3).

PART VIII—DETERMINING DENSITY OF PERMEABLE FRICTION COURSE (PFC) AND THIN BONDED WEARING COURSE (TBWC) MIXTURES

33. SCOPE

33.1 Use this procedure to back-calculate the G_r of loose PFC and TBWC mixtures, to calculate the Ga of laboratory-molded specimens for PFC and TBWC mixtures using dimensional analysis, and to calculate density of compacted PFC and TBWC mixtures.

34. APPARATUS

34.1 *Measuring Device*, such as a ruler, calipers, or measuring tape.

35. PROCEDURE

35.1 Back calculate G_r.

35.1.1 Obtain the G_e of the combined aggregate blend.

Note 37—Obtain the G_e from the Summary worksheet of the Mix Design Template.

35.1.2 Record and designate this as Ge in Section 36.1.

35.1.3 Determine the AC of the PFC or TBWC mixture.

Note 38—Determine the AC of PFC-Asphalt Rubber (AR) mixtures by using the asphalt flow meter. Determine the AC of PFC PG 76 mixtures using an ignition oven in accordance with Tex-236-F or by using the asphalt flow meter

35.1.4 Record and designate this as A_s in Section 36.1.

35.1.5 Determine the specific gravity of the asphalt binder. Round to three decimal places (0.001).

35.1.6 Record and designate this as G_s in Section 36.1.

35.1.7 Calculate G_r as noted in Section 36.1.

35.2 Calculate G_a using dimensional analysis.

35.2.1 Measure the weight of the laboratory molded specimen in air, to the nearest 0.1 g.

35.2.2 Record and designate this weight as *W* in Section 36.2.

35.2.3 Measure the height of the laboratory-molded specimen, to the nearest 0.1 mm.

35.2.4 Record and designate this height as *h* in Section 36.2.

35.2.5 Measure the diameter of the laboratory-molded specimen, to the nearest 0.1 mm.

Note 39—The diameter for specimens molded with a Superpave Gyratory Compactor is 150 mm.

35.2.6 Calculate the radius of the laboratory-molded specimen by dividing the diameter, as determined in Section 34.2.5, by 2.

Note 40—The radius for specimens molded with a Superpave Gyratory Compactor is 75 mm.

35.2.7 Record and designate this as *r* in Section 36.2.

35.2.8 Calculate G_a as noted in Section 36.2.

Note 41—Numerical value for π is 3.14.

35.3 Calculate density of compacted PFC or TBWC mixture.

35.3.1 Divide the G_a determined in Section 35.2.8 by the G_r determined in Section 35.1.7.

35.3.2 Multiply the results from Section 35.3.1 by 100.

Note 42—Round this calculated value to the tenth decimal place (0.1).

36. CALCULATIONS

36.1 Calculate the G_r of the loose PFC or TBWC mixture:

$$G_r = \frac{100}{[\left(\frac{100 - A_s}{G_e}\right) + \left(\frac{A_s}{G_s}\right)]}$$

Where:
G_r = theoretical maximum specific gravity,
G_e = effective specific gravity, %,
A_s = AC, %,and
G_s = asphalt binder specific gravity, 0.001.

36.2 Calculate the Ga of the compacted specimen:

$$G_a = \frac{[\frac{W}{\pi^2 h}]}{\gamma}$$

Where:
G_a = bulk specific gravity,
W = weight of specimen, 0.1 g,
π = pi, 3.14,
r = radius of specimen, 1 mm,
h = height of specimen, 0.1 mm, and
γ = density of water, 0.001 g/mm^3.

37. REPORT FORMAT
37.1 Use the following Excel programs to calculate and report density test results.
37.1.1 Quality Control/Quality Assurance (QC/QA), used in conjunction with the hot mix specification and test data worksheets. Refer to the "Help" tab for detailed instructions on how to use the program.
37.1.2 Segregation Density Profile Form.
37.1.3 Longitudinal Joint Density Profile Form.

38. ARCHIVED VERSIONS
38.1 Archived versions are available.

TEXAS DEPARTMENT OF TRANSPORTATION

SEGREGATION PROFILE_1
TEX-207-F, PART V

Refresh Workbook   Segregation Profile :: File Version: 02/16/20 19:33:06

SAMPLE ID:		SAMPLED DATE:	
TEST NUMBER:		LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	
COUNTY:		SPEC YEAR:	
SAMPLED BY:		SPEC ITEM:	
SAMPLE LOCATION:		SPECIAL PROVISION:	
MATERIAL CODE:		MIX TYPE:	
MATERIAL NAME:			
PRODUCER:			
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:	

TYPE OF DENSITY GAUGE:		**LOT:**		**SUBLOT:**	

**** Select 'Mix Type' Before Entering Test Results ****
**** Three Density Readings Are Required At Each Location ****

LOCATION	DENSITY READINGS					AVERAGE
	1	2	3			
0'						
5'						
10'						
15'						
20'						
25'						
30'						
35'						
40'						
45'						
50'						

AVERAGE READING:	
HIGH READING:	
LOW READING:	

MAX ALLOWABLE DENSITY RANGE	
HIGHEST TO LOWEST:	
AVERAGE TO LOWEST:	

Remarks:

Test Method:	Tested By:	Tested Date:
TX207		
TX207V		

Test Stamp Code:	Omit Test:	Completed Date:	Reviewed By:

Locked By:	TxDOT:	District:	Area:

Authorized By:	Authorized Date:

Example (5/1/2007)

TEXAS DEPARTMENT OF TRANSPORTATION

SEGREGATION PROFILE
TEX-207-F, PART V

Refresh Workbook

File Version: 12/12/06 10:12:43

SAMPLE ID:		SAMPLED DATE:	05/01/2007
TEST NUMBER:		LETTING DATE:	
STATUS:		CONTROLLING CSJ:	
COUNTY:		SPEC YEAR:	2004
SAMPLED BY:		SPEC ITEM:	
SAMPLE LOCATION:		SPECIAL PROVISION:	NONE
MATERIAL:		MIX TYPE:	Type C
PRODUCER:			
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:	Surface	STATION:		DIST. FROM CL:	

TYPE OF DENSITY GAUGE:	**Nuclear**

LOCATION	DENSITY READINGS					AVERAGE
	1	2	3			
0'	142.0	141.0	142.7			141.9
5'	139.2	138.2	138.7			138.7
10'	140.2	140.9	140.5			140.5
15'	141.2	141.7	142.3			141.7
20'	138.9	138.2	137.7			138.3
25'	137.2	137.5	136.9			137.2
30'	139.4	139.5	139.7			139.5
35'	137.3	137.5	137.6			137.5
40'	140.2	140.3	140.9			140.5
45'	142.3	141.9	141.2			141.8
50'	140.3	140.5	139.8			140.2

AVERAGE READING:	139.8
HIGH READING:	141.9
LOW READING:	137.2

MAX ALLOWABLE DENSITY RANGE	
HIGHEST TO LOWEST:	4.7
AVERAGE TO LOWEST:	2.6

Remarks:

Test Method:	Tested By:	Tested Date:
TX207		

Reviewed By:	Completed Date:

Authorized By:	Authorized Date:

THERMAL PROFILE OF HOT MIX ASPHALT

TxDOT Designation: Tex-244-F

Effective Date: December 2015

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1. SCOPE

1.1 Use this test method to obtain a thermal profile that identifies the presence of thermal segregation of an uncompacted mat of hot mix asphalt. This method includes procedures for determining thermal profile using:

- a hand-held thermal camera immediately behind the paver during uninterrupted paving operations, or
- a paver-mounted thermal imaging system.

1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. APPARATUS

2.1 *Thermal camera or thermal imaging system.*

2.1.1 Hand-held thermal camera must be capable of:

- measuring from 40°F to 475°F with an accuracy of ± 4□F or ± 2% of reading, whichever is greater;
- producing an IR image minimum resolution of 19,200 pixels;
- displaying the maximum temperature and minimum temperature using a LCD viewing screen with a minimum diagonal dimension of 3.0 in.;
- storing a minimum of 50 images and capable of opening images while in operation;
- a thermal sensitivity less than 0.15□F; and
- a variable emissivity from 0.1 to 1.0.

2.1.2 Paver-mounted thermal imaging system must be capable of:

- measuring at a maximum transverse spacing of 12 ± 1 in.;
- using infrared sensors to measure from 40–475°F with an accuracy of ± 3.5□F or ± 1.5% of reading, whichever is greater, when the object temperature exceeds 32°F and the ambient temperature is 73 ± 9°F;
- having temperature measurement repeatability of ± 1.8°F or ± 0.75% of reading, whichever is greater;
- measuring spots with a maximum size of 10 in. at the installed operating height;

- profiling the entire pavement width, up to at least 12 ft. wide, with provisions to prevent areas within 2 ft. of the edge of the uncompacted mat from influencing the thermal profile results;
- measuring distance using a Distance Measuring Instrument (DMI) and equipped with a Global Positioning System (GPS);
- collecting, displaying, saving, and analyzing temperature readings while in operation, using the latest software available;
- determining the low and high temperatures within each profile using the statistical 1 percentile and 98.5 percentile, respectively;
- producing output files of pavement temperatures for each day's placement and daily summary output files in an approved test report that identifies locations of thermal segregation with a recording of the temperature at such locations;
- providing software capable of developing and analyzing thermal profiles for the entire project; and
- providing an operating system with at least one USB port to save test results to a portable USB memory device.

3. REPORT FORMS

3.1 Tx244-4.xlsm, "Thermal Profile of Hot Mix Asphalt (4 Sublots Included)."

4. PROCEDURE

4.1 Operate the thermal imaging camera or thermal imaging system in accordance with the manufacturer's recommendations.

4.2 Obtain a new maximum baseline temperature and minimum profile temperature for every thermal profile measured.

4.3 Record the beginning and ending station numbers of all thermal profiles.

Note 1—Instead of station numbers, use of GPS coordinates or other approved means of identifying the locations is acceptable.

4.4 Obtain all temperature measurements in units of degrees Fahrenheit.

4.5 Obtain all temperature measurements while the paver is moving.

4.6 If the paver stops for more than 60 sec., exclude the area 2 ft. behind and 8 ft. in front (in the direction of travel) of the last temperature measurement.

4.7 Proceed to Section 4.8 when using a thermal imaging camera. Proceed to Section 4.9 when using a thermal imaging system.

4.8 *Using the Thermal Camera:*

4.8.1 Mark the pavement edge at the beginning and ending location of each thermal profile using spray paint or a permanent marker. Refer to Figure 1.

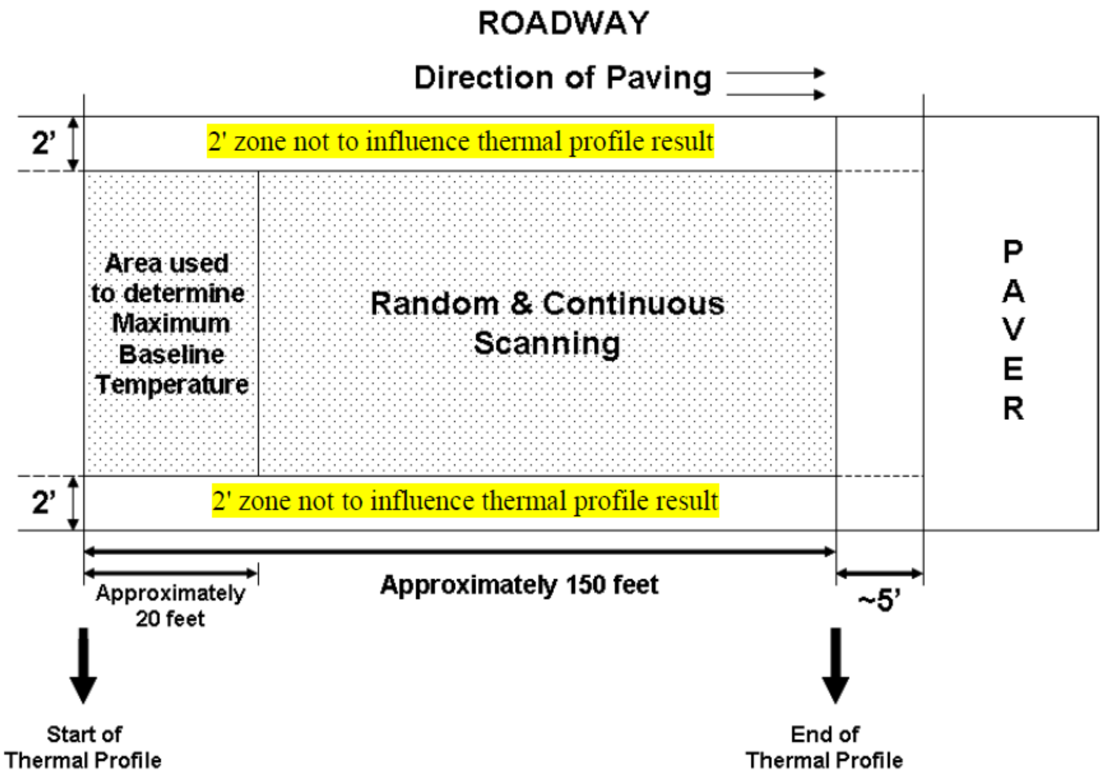


Figure 1—Thermal Profile when Using a Handheld Thermal Camera

4.8.2 Configure the thermal camera to achieve the optimum brightness and contrast of the display image and to adjust the minimum and maximum temperature levels automatically while performing thermal profiles. Do not manually enter the minimum and maximum temperature levels.

Note 2—Thermal cameras are generally equipped with an auto-adjusting feature, which automatically adjusts the minimum and maximum temperature levels, brightness, and contrast.

4.8.3 Observe the paving operations to determine the approximate distance the paver travels until the roller compacts the mat.

4.8.4 Determine the maximum baseline temperature over a paving distance of approximately 20 ft. (6.1 m).

Note 3—Each thermal profile will be approximately 150 ft. This distance includes the 20 ft. used to establish the maximum baseline temperature when profiling with a thermal imaging camera.

4.8.4.1 Stand at the edge of the uncompacted mat at a distance of approximately 5 ft. behind the paver, or stand on the paver screed.

Note 4—Follow all safety precautions and guidelines when standing on the paver screed.

4.8.4.2 Determine the lowest allowable profile temperature by subtracting 25F from the maximum baseline temperature measured in Section 4.8.4.

4.8.5 Measure the temperature of the uncompacted mat in a zone approximately 5–15 feet behind the paver by pointing the thermal camera and squeezing the trigger. Avoid taking temperature measurements within 2 ft. of the edge of the uncompacted mat.

Note 5—When standing on the paver screed, refer to the manufacturer's instructions for determining the relationship between the field of view and distance to determine the proper zone for evaluation within the thermal camera's image. When standing at the edge of the uncompacted mat, pointing the thermal camera at a 90-degree angle to the direction of paving can ensure temperature data collected is within the required zone behind the paver.

Note 6—Avoid measuring high temperature areas caused by heating from the screed while the paver is stopped.

4.8.5.1 Save the image to the memory of the thermal camera.

Note 7—Additional images will be necessary to evaluate the total paving distance.

4.8.6 Following Section 4.8.5, determine the lowest temperature measured throughout the thermal profile over a paving distance of approximately 130 ft. Designate this as minimum profile temperature.

4.8.7 Record the low temperature obtained in Section 4.8.6, using spray paint or a permanent marker at the edge of the paving lane to indicate any area of the mat in which the profile is less than the lowest allowable profile temperature established in Section 4.8.4.2.

4.8.8 Record the station number to identify the location of the mat for the low temperature measured in Section 4.8.6.

Note 8—Instead of station numbers, GPS coordinates or other acceptable means may be used to identify the location.

4.8.9 Proceed to Section 5.1.

4.9 *Using the Thermal Imaging System:*

4.9.1 Refer to the summary output file for locations when using the thermal imaging system. Refer to Figure 2.

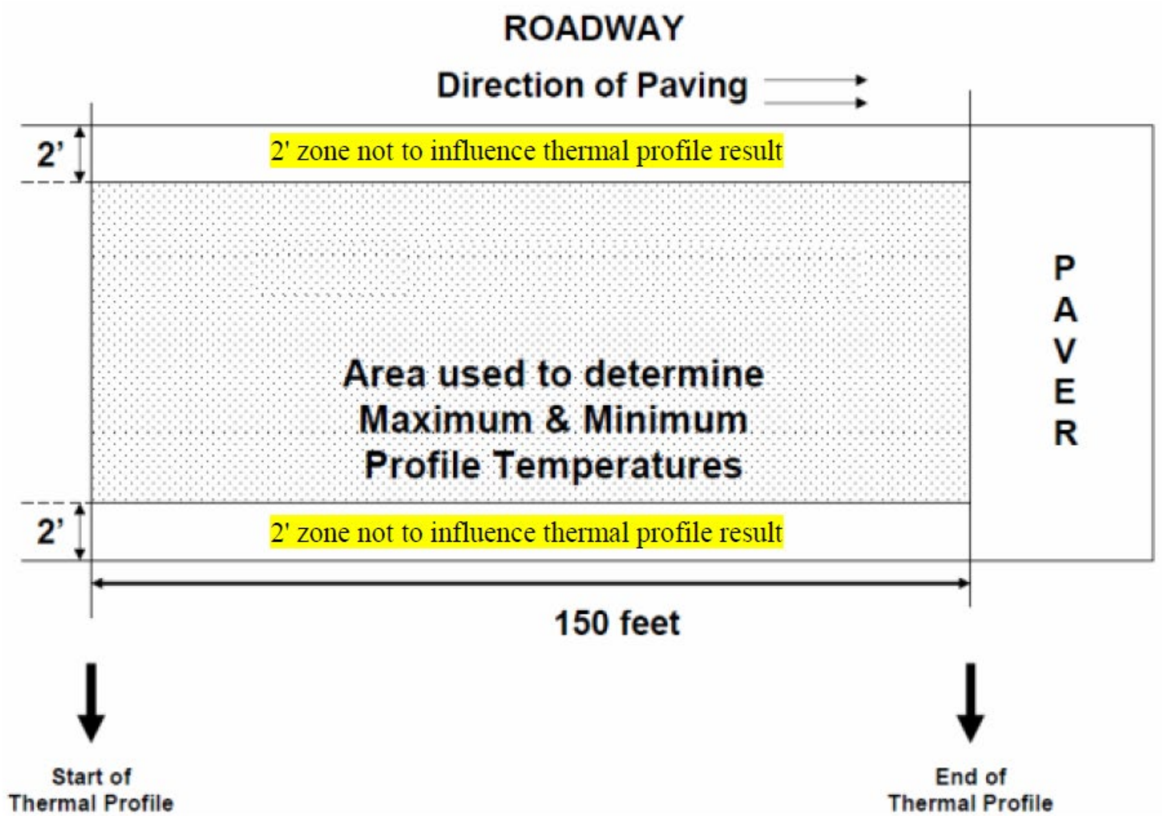


Figure 2—Thermal Profile when Using a Thermal Imaging System

4.9.2 Obtain the maximum baseline temperature when using the thermal imaging system by analyzing the temperature readings recorded throughout the entire 150-ft. length.
4.9.3 Install and operate the thermal imaging system on the paver following the manufacturer's recommendations.
4.9.4 Verify the calibration for each temperature sensor prior to collecting temperature measurements per manufacturer's recommendations.
Note 9—Check calibration of each temperature sensor to a known standard on an annual basis and recalibrate if necessary. Document the yearly check/calibration result.

4.9.5 Configure the thermal imaging system to record pavement temperatures at increments of no more than 12 in. of forward movement.
4.9.6 Generate the automated test report produced by the thermal imaging system from the temperature readings measured in Section 4.9.4.
Note 10—The test report must include the temperatures and locations (station numbers, GPS coordinates, or other acceptable means) where moderate or severe thermal segregation exists.

4.9.7 Proceed to Section 5.2.

5. CALCULATIONS

5.1 Calculate and record the temperature differential of the uncompacted mat surface when using a thermal camera:

Temperature Differential = Maximum Baseline Temperature - Minimum Profile Temperature

Note 11—Designate the Temperature Differential as having no thermal segregation, moderate thermal segregation, or severe thermal segregation.

5.2 Calculate and record the temperature differential of the uncompacted mat surface when using a thermal imaging system:

Temperature Differential = Maximum Temperature Recorded - Minimum Temperature Recorded

Note 12—The minimum and maximum temperatures within each profile are determined using the statistical 1 percentile and 98.5 percentile, respectively

6. ARCHIVED VERSIONS

6.1 Archived versions are available.

TEXAS DEPARTMENT OF TRANSPORTATION

THERMAL PROFILE OF HOT MIX ASPHALT

Tex-244-F

Refresh Workbook

TX244 :: File Version: 05/24/17 13:16:49

SAMPLE ID:		SAMPLED DATE:	
TEST NUMBER:		LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	
COUNTY:		SPEC YEAR:	
SAMPLED BY:		SPEC ITEM:	
SAMPLE LOCATION:		SPECIAL PROVISION:	
MATERIAL CODE:		GRADE:	
MATERIAL NAME:			
PRODUCER:			
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:	

LOT NUMBER:		**EQUIPMENT USED:**	

	1	2	3	4
SUBLOT NUMBER:				
Starting Station:				
Ending Station:				
Maximum Baseline Temperature, °F:				
Lowest Allowable Profile Temperature, °F:				
Minimum Profile Temperature, °F:				
Temperature Differential, °F:				

Number of Profiles:	

Moderate 25.0°F < differential <= 50.0°F		Severe differential > 50.0°F	
Number	Percent	Number	Percent

Remarks:

Test Method:	Tested By:		Tested Date:
TX244			

Test Stamp Code:	Omit Test:	Completed Date:	Reviewed By:

Locked By:	TxDOT:	District:	Area:

Authorized By:	Authorized Date:	
		1

http://www.dot.state.tx.us/apps-cg/specs/ShowAll.asp?year=4&type=SS&number=3

2014 English Special Specifications to Items 3000 - 3999 Surface Courses/Pavements (All)

SS3077 PDF RTF **Superpave Mixtures** - This special specification will replace Item 344 in the 2014 Standard Specifications. *Required for all projects using superpave mixtures beginning with the February 2020 letting.* **Statewide Use.**

Texas Special Specification 3077 – Superpave Mixtures (excerpts)

Special Specification 3077

Superpave Mixtures

Texas Department of Transportation

1. Description

Construct a hot-mix asphalt (HMA) pavement layer composed of a compacted, Superpave (SP) mixture of aggregate and asphalt binder mixed hot in a mixing plant. Payment adjustments will apply to HMA placed under this specification unless the HMA is deemed exempt in accordance with Section 3077.4.9.4., "Exempt Production."

2. Materials

. . .

4. Construction

Produce, haul, place, and compact the specified paving mixture. In addition to tests required by the specification, Contractors may perform other QC tests as deemed necessary. At any time during the project, the Engineer may perform production and placement tests as deemed necessary in accordance with Item 5, "Control of the Work." Schedule and participate in a mandatory pre-paving meeting with the Engineer on or before the first day of paving unless otherwise shown on the plans.

4.1 Certification. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 6. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level 2 certified specialist. Provide Level 1A certified specialists at the plant during production operations. Provide Level 1B certified specialists to conduct placement tests. Provide AGG101 certified specialists for aggregate testing.

Table 6
Test Methods, Test Responsibility, and Minimum Certification Levels

Test Description	Test Method	Contractor	Engineer	Level[1]
1. Aggregate and Recycled Material Testing				
Sampling	Tex-221-F	✓	✓	1A/AGG101
Dry sieve	Tex-200-F, Part I	✓	✓	1A/AGG101
Washed sieve	Tex-200-F, Part II	✓	✓	1A/AGG101
Deleterious material	Tex-217-F, Parts I & III	✓	✓	AGG101
Decantation	Tex-217-F, Part II	✓	✓	AGG101
Los Angeles abrasion	Tex-410-A		✓	TxDOT
Magnesium sulfate soundness	Tex-411-A		✓	TxDOT
Micro-Deval abrasion	Tex-461-A		✓	AGG101
Crushed face count	Tex-460-A	✓	✓	AGG101
Flat and elongated particles	Tex-280-F	✓	✓	AGG101
Linear shrinkage	Tex-107-E	✓	✓	AGG101
Sand equivalent	Tex-203-F	✓	✓	AGG101
Bulk specific gravity	Tex-201-F	✓	✓	AGG101
Unit weight	Tex-404-A	✓	✓	AGG101
Organic impurities	Tex-408-A	✓	✓	AGG101
2. Asphalt Binder & Tack Coat Sampling				
Asphalt binder sampling	Tex-500-C, Part II	✓	✓	1A/1B
Tack coat sampling	Tex-500-C, Part III	✓	✓	1A/1B
3. Mix Design & Verification				
Design and JMF changes	Tex-204-F	✓	✓	2
Mixing	Tex-205-F	✓	✓	2
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F, Parts I & VI	✓	✓	1A
Rice gravity	Tex-227-F, Part II	✓	✓	1A
Ignition oven correction factors[2]	Tex-236-F, Part II	✓	✓	2
Indirect tensile strength	Tex-226-F	✓	✓	1A
Hamburg Wheel test	Tex-242-F	✓	✓	1A
Boil test	Tex-530-C	✓	✓	1A
4. Production Testing				
Selecting production random numbers	Tex-225-F, Part I		✓	1A
Mixture sampling	Tex-222-F	✓	✓	1A/1B
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F, Parts I & VI	✓	✓	1A
Rice gravity	Tex-227-F, Part II	✓	✓	1A
Gradation & asphalt binder content[2]	Tex-236-F, Part I	✓	✓	1A
Control charts	Tex-233-F	✓	✓	1A
Moisture content	Tex-212-F, Part II	✓	✓	1A/AGG101
Hamburg Wheel test	Tex-242-F	✓	✓	1A
Micro-Deval abrasion	Tex-461-A		✓	AGG101
Boil test	Tex-530-C	✓	✓	1A
Abson recovery	Tex-211-F		✓	TxDOT
5. Placement Testing				
Selecting placement random numbers	Tex-225-F, Part II		✓	1B
Trimming roadway cores	Tex-251-F, Parts I & II	✓	✓	1A/1B
In-place air voids	Tex-207-F, Parts I & VI	✓	✓	1A
In-place density (nuclear method)	Tex-207-F, Part III	✓		1B
Establish rolling pattern	Tex-207-F, Part IV	✓		1B
Control charts	Tex-233-F	✓	✓	1A
Ride quality measurement	Tex-1001-S	✓	✓	Note 3
Segregation (density profile)	Tex-207-F, Part V	✓	✓	1B
Longitudinal joint density	Tex-207-F, Part VII	✓	✓	1B
Thermal profile	Tex-244-F	✓	✓	1B
Shear Bond Strength Test	Tex-249-F		✓	TxDOT

1. Level 1A, 1B, AGG101, and 2 are certification levels provided by the Hot Mix Asphalt Center certification program.
2. Refer to Section 3077.4.9.2.3., "Production Testing," for exceptions to using an ignition oven.
3. Profiler and operator are required to be certified at the Texas A&M Transportation Institute facility when Surface Test Type B is specified

4.2 Reporting and Responsibilities. Use Department-provided templates to record and calculate all test data, including mixture design, production and placement QC/QA, control charts, thermal profiles, segregation density profiles, and longitudinal joint density. Obtain the current version of the templates at http://www.txdot.gov/inside-txdot/forms-publications/consultants-contractors/forms/site-manager.html or from the Engineer. The Engineer and the Contractor will provide any available test results to the other party when requested. The maximum allowable time for the Contractor and Engineer to exchange test data is as given in Table 7 unless otherwise approved. The Engineer and the Contractor will immediately report to the other party any test result that requires suspension of production or placement, a payment adjustment less than 1.000, or that fails to meet the specification requirements. Record and electronically submit all test results and pertinent information on Department-provided templates.

Subsequent sublots placed after test results are available to the Contractor, which require suspension of operations, may be considered unauthorized work. Unauthorized work will be accepted or rejected at the discretion of the Engineer in accordance with Article 5.3., “Conformity with Plans, Specifications, and Special Provisions.”

Table 7
Reporting Schedule

Description	Reported By	Reported To	To Be Reported Within
Production Quality Control			
Gradation[1]	Contractor	Engineer	1 working day of completion of the sublot
Asphalt binder content[1]			
Laboratory-molded density[2]			
Moisture content[3]			
Boil test[3]			
Production Quality Assurance			
Gradation[3]	Engineer	Contractor	1 working day of completion of the sublot
Asphalt binder content[3]			
Laboratory-molded density[1]			
Hamburg Wheel test[4]			
Boil test[3]			
Binder tests[4]			
Placement Quality Control			
In-place air voids[2]	Contractor	Engineer	1 working day of completion of the lot
Segregation[1]			
Longitudinal joint density[1]			
Thermal profile[1]			
Placement Quality Assurance			
In-place air voids[1]	Engineer	Contractor	1 working day after receiving the trimmed cores[5]
Segregation[3]			1 working day of completion of the lot
Longitudinal joint density[3]			
Thermal profile[3]			
Aging ratio[4]			
Payment adjustment summary	Engineer	Contractor	2 working days of performing all required tests and receiving Contractor test data

1. These tests are required on every sublot.
2. Optional test. When performed on split samples, report the results as soon as they become available.
3. To be performed at the frequency specified in Table 17 or as shown on the plans.
4. To be reported as soon as the results become available.
5. Two days are allowed if cores cannot be dried to constant weight within 1 day.

. . .

4.3 Quality Control Plan (QCP). Develop and follow the QCP in detail. Obtain approval for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP before the mandatory pre-paving meeting. Receive approval of the QCP before beginning production. Include the following items in the QCP:

. . .

4.3.2 Material Delivery and Storage. For material delivery and storage, include:

- the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;
- aggregate stockpiling procedures to avoid contamination and segregation;
- frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
- procedure for monitoring the quality and variability of asphalt binder.

4.3.3 Production. For production, include:

- loader operation procedures to avoid contamination in cold bins;
- procedures for calibrating and controlling cold feeds;
- procedures to eliminate debris or oversized material;
- procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, RAS, lime, liquid antistrip, WMA);
- procedures for reporting job control test results; and
- procedures to avoid segregation and drain-down in the silo.

4.3.4 Loading and Transporting. For loading and transporting, include:

- type and application method for release agents; and
- truck loading procedures to avoid segregation.

4.3.5 Placement and Compaction. For placement and compaction, include:

- proposed agenda for mandatory pre-paving meeting, including date and location;
- proposed paving plan (e.g., paving widths, joint offsets, and lift thicknesses);
- type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;
- procedures for the transfer of mixture into the paver, while avoiding segregation and preventing material spillage;
- process to balance production, delivery, paving, and compaction to achieve continuous placement operations and good ride quality;
- paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
- procedures to construct quality longitudinal and transverse joints.

. . .

4.7.1.1. When Using a Thermal Imaging System. Place mixture when the roadway is dry and the roadway surface temperature is at or above the temperatures listed in Table 15A.The Engineer may restrict the Contractor from paving surface mixtures if the ambient temperature is likely to drop below 32°F within 12 hr. of paving. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. Provide output data from the thermal imaging system to demonstrate to the Engineer that no recurring severe thermal segregation exists in accordance with Section 3077.4.7.3.1.2., “Thermal Imaging System.”

Table 15A
Minimum Pavement Surface Temperatures

High-Temperature Binder Grade[1]	Minimum Pavement Surface Temperatures (°F)	
	Subsurface Layers or Night Paving Operations	Surface Layers Placed in Daylight Operations
PG 64	35	40
PG 70	45[2]	50[2]
PG 76	45[2]	50[2]

1. The high-temperature binder grade refers to the high-temperature grade of the virgin asphalt binder used to produce the mixture.
2. Contractors may pave at temperatures 10°F lower than these values when a chemical WMA additive is used as a compaction aid in the mixture or when using WMA.

4.7.1.2. When Not Using a Thermal Imaging System. When using a thermal camera instead of the thermal imaging system, place mixture when the roadway surface temperature is at or above the temperatures listed in Table 15B unless otherwise approved or as shown on the plans. Measure the roadway surface temperature with a hand-held thermal camera or infrared thermometer. The Engineer may allow mixture placement to begin before the roadway surface reaches the required temperature if conditions are such that the roadway surface will reach the required temperature within 2 hr. of beginning placement operations. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. The Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving.

Table 15B
Minimum Pavement Surface Temperatures

High-Temperature Binder Grade[1]	Minimum Pavement Surface Temperatures (°F)	
	Subsurface Layers or Night Paving Operations	Surface Layers Placed in Daylight Operations
PG 64	45	50
PG 70	55[2]	60[2]
PG 76	60[2]	60[2]

1. The high-temperature binder grade refers to the high-temperature grade of the virgin asphalt binder used to produce the mixture.
2. Contractors may pave at temperatures 10°F lower than these values when a chemical WMA additive is used as a compaction aid in the mixture, when using WMA, or utilizing a paving process with equipment that eliminates thermal segregation. In such cases, for each sublot and in the presence of the Engineer, use a hand-held thermal camera operated in accordance with Tex-244-F to demonstrate to the satisfaction of the Engineer that the uncompacted mat has no more than 10°F of thermal segregation.

4.7.3.1.1 Thermal Segregation.

4.7.3.1.1.1. Moderate. Any areas that have a temperature differential greater than 25°F, but not exceeding 50°F, are deemed as moderate thermal segregation.

4.7.3.1.1.2. Severe. Any areas that have a temperature differential greater than 50°F are deemed as severe thermal segregation.

4.7.3.1.2. Thermal Imaging System. Review the output results when a thermal imaging system is used, and provide the automated report described in Tex-244-F to the Engineer daily unless otherwise directed. Modify the paving process as necessary to eliminate any recurring (moderate or severe) thermal segregation identified by the thermal imaging system. The Engineer may suspend paving operations if the Contractor cannot successfully modify the paving process to eliminate recurring severe thermal segregation. Density profiles are not required and not applicable when using a thermal imaging system. Provide the Engineer with electronic copies of all daily data files that can be used with the thermal imaging system software to generate temperature profile plots daily or upon completion of the project or as requested by the Engineer.

5.7.3.1.3. Thermal Camera. When using a thermal camera instead of the thermal imaging system, take immediate corrective action to eliminate recurring moderate thermal segregation when a hand-held thermal camera is used. Evaluate areas with moderate thermal segregation by performing density profiles in accordance with Section 3077.4.9.3.3.2., "Segregation (Density Profile)." Provide the Engineer with the thermal profile of every sublot within one working day of the completion of each lot. When requested by the Engineer, provide the thermal images generated using the thermal camera. Report the results of each thermal profile in accordance with Section 3077.4.2., "Reporting and Responsibilities." The Engineer will use a hand-held thermal camera to obtain a thermal profile at least once per project. No production or placement payment adjustments greater than 1.000 will be paid for any sublot that contains severe thermal segregation. Suspend operations and take immediate corrective action to eliminate severe thermal segregation unless otherwise directed. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Section. Evaluate areas with severe thermal segregation by performing density profiles in accordance with Section 3077.4.9.3.3.2., "Segregation (Density Profile)." Remove and replace the material in any areas that have both severe thermal segregation and a failing result for Segregation (Density Profile) unless otherwise directed. The sublot in question may receive a production and placement payment adjustment greater than 1.000, if applicable, when the defective material is successfully removed and replaced.

4.9.2.3. Production Testing. The Contractor and Engineer must perform production tests in accordance with Table 17. The Contractor has the option to verify the Engineer's test results on split samples provided by the Engineer. Determine compliance with operational tolerances listed in Table 12 for all sublots.

Take immediate corrective action if the Engineer's laboratory-molded density on any sublot is less than 95.0% or greater than 97.0% to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

The Engineer may allow alternate methods for determining the asphalt binder content and aggregate gradation if the aggregate mineralogy is such that Tex-236-F, Part I does not yield reliable results. Provide evidence that results from Tex-236-F, Part I are not reliable before requesting permission to use an alternate method unless otherwise directed. Use the applicable test procedure as directed if an alternate test method is allowed.

Table 17
Production and Placement Testing Frequency

Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	1 per sublot	1 per 12 sublots[1]
Individual % retained for sieves smaller than #8 and larger than #200			
% passing the #200 sieve			
Laboratory-molded density	Tex-207-F	N/A	1 per sublot[1]
Laboratory-molded bulk specific gravity			
In-place air voids			
VMA	Tex-204-F		
Segregation (density profile)	Tex-207-F, Part V	1 per sublot[2]	1 per project
Longitudinal joint density	Tex-207-F, Part VII		
Moisture content	Tex-212-F, Part II	When directed	
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	1 per sublot[1]
Asphalt binder content	Tex-236-F	1 per sublot	1 per lot[1]
Hamburg Wheel test	Tex-242-F	N/A	1 per project
Recycled Asphalt Shingles (RAS)[3]	Tex-217-F, Part III	N/A	
Thermal profile	Tex-244-F	1 per sublot[2]	
Asphalt binder sampling and testing	Tex-500-C, Part II	1 per lot (sample only)[4]	
Tack coat sampling and testing	Tex-500-C, Part III	N/A	
Boil test[5]	Tex-530-C	1 per lot	
Shear Bond Strength Test[6]	Tex-249-F	1 per project (sample only)	

1. For production defined in Section 3077.4.9.4., "Exempt Production," the Engineer will test one per day if 100 tons or more are produced. For Exempt Production, no testing is required when less than 100 tons are produced.
2. To be performed in the presence of the Engineer, unless otherwise approved. Not required when a thermal imaging system is used.
3. Testing performed by the Materials and Tests Division or designated laboratory.
4. Obtain samples witnessed by the Engineer. The Engineer will retain these samples for one year.
5. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.
6. Testing performed by the Materials and Tests Division or District for informational purposes only.

4.9.3.3.2. Segregation (Density Profile). Test for segregation using density profiles in accordance with Tex-207-F, Part V when using a thermal camera instead of the thermal imaging system. Density profiles are not required and are not applicable when using a thermal imaging system. Density profiles are not applicable in areas described in Section 3077.4.9.3.1.4., "Miscellaneous Areas."

Perform a minimum of one density profile per sublot. Perform additional density profiles when any of the following conditions occur, unless otherwise approved:

- the paver stops due to lack of material being delivered to the paving operations and the temperature of the uncompacted mat before the initial break down rolling is less than the temperatures shown in Table 18;
- areas that are identified by either the Contractor or the Engineer with thermal segregation;
- any visibly segregated areas that exist.

Table 18
Minimum Uncompacted Mat Temperature Requiring a Segregation Profile

High-Temperature Binder Grade[1]	Minimum Temperature of the Uncompacted Mat Allowed Before Initial Break Down Rolling[2,3,4]
PG 64	<250°F
PG 70	<260°F
PG 76	<270°F

1. The high-temperature binder grade refers to the high-temperature grade of the virgin asphalt binder used to produce the mixture.
2. Segregation profiles are required in areas with moderate and severe thermal segregation as described in Section 3077.4.7.3.1.3.
3. Minimum uncompacted mat temperature requiring a segregation profile may be reduced 10°F if using a chemical WMA additive as a compaction aid.
4. When using WMA, the minimum uncompacted mat temperature requiring a segregation profile is 215°F.

Provide the Engineer with the density profile of every sublot in the lot within one working day of the completion of each lot. Report the results of each density profile in accordance with Section 3077.4.2., "Reporting and Responsibilities."

The density profile is considered failing if it exceeds the tolerances in Table 19. No production or placement payment adjustments greater than 1.000 will be paid for any sublot that contains a failing density profile. When a hand-held thermal camera is used instead of a thermal imaging system, the Engineer will measure the density profile at least once per project. The Engineer's density profile results will be used when available. The Engineer may require the Contractor to remove and replace the area in question if the area fails the density profile and has surface irregularities as defined in Section 3077.4.9.3.3.5., "Irregularities." The sublot in question may receive a production and placement payment adjustment greater than 1.000, if applicable, when the defective material is successfully removed and replaced.

Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if two consecutive density profiles fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Table 19
Segregation (Density Profile) Acceptance Criteria

Mixture Type	Maximum Allowable Density Range (Highest to Lowest)	Maximum Allowable Density Range (Average to Lowest)
SP-B	8.0 pcf	5.0 pcf
SP-C & SP-D	6.0 pcf	3.0 pcf

4.9.3.3.5. Irregularities. Identify and correct irregularities including segregation, rutting, raveling, flushing, fat spots, mat slippage, irregular color, irregular texture, roller marks, tears, gouges, streaks, uncoated aggregate particles, or broken aggregate particles. The Engineer may also identify irregularities, and in such cases, the Engineer will promptly notify the Contractor. If the Engineer determines that the irregularity will adversely affect pavement performance, the Engineer may require the Contractor to remove and replace (at the Contractor's expense) areas of the pavement that contain irregularities. The Engineer may also require the Contractor to remove and replace (at the Contractor's expense) areas where the mixture does not bond to the existing pavement.

6. Payment

. . .

Payment for each sublot, including applicable payment adjustments greater than 1.000, will only be paid for sublots when the Contractor supplies the Engineer with the required documentation for production and placement QC/QA, thermal profiles, segregation density profiles, and longitudinal joint densities in accordance with Section 3077.4.2., "Reporting and Responsibilities." When a thermal imaging system is used, documentation is not required for thermal profiles or segregation density profiles on individual sublots; however, the thermal imaging system automated reports described in Tex-244-F are required.

Washington

Q7 response: WSDOT Standard Specification Section 5-04.3(10)B HMA Compaction – Cyclic Density

P. 5-53:

5-04.3(10)B HMA Compaction – Cyclic Density

Low cyclic density areas are defined as spots or streaks in the pavement that are less than 90 percent of the theoretical maximum density. At the Engineer's discretion, the Engineer may evaluate the HMA pavement for low cyclic density, and when doing so will follow WSDOT SOP 733. A $500 Cyclic Density Price Adjustment will be assessed for any 500-foot section with two or more density readings below 90 percent of the theoretical maximum density.

Washington State Department of Transportation

WSDOT SOP 733

Determination of Pavement Density Differentials Using the Nuclear Density Gauge

WSDOT SOP 733

Determination of Pavement Density Differentials Using the Nuclear Density Gauge

1. Scope

This test method describes the procedure for locating and testing areas of suspected low cyclic density. Lower pavement density has been related to temperature differentials and areas of "spots, streaks" or visual pavement irregularities. This method uses infrared detection devices and visual inspection to identify areas of potentially low cyclic density.

2. Definitions

a. Temperature Differential Area- Any area where the temperature of the newly placed HMA pavement is greater than 25° F different than the surrounding area.

b. Aggregate segregation- "Spots, streaks" or visual pavement irregularities in the newly placed HMA pavement that has a significant difference in texture when compared to the surrounding material.

c. Systematic Density Testing - the testing of temperature differential areas or areas of aggregate segregation to determine if there is a pattern of low cyclic density.

3. Equipment

a. An approved infrared camera OR a handheld noncontact infrared thermometer (features for both should include continuous reading, minimum, maximum, and average readings, laser sighting, and a minimum distance to spot size ratio (D:S) of 30:1.
b. Nuclear moisture-density gauge.
c. Tape measure.
d. A can of spray paint for marking test locations.
e. Required report form.

4. Testing Criteria

a. Where temperature differentials are 25° F or greater a systematic HMA compaction test is required.
b. Where temperature differentials are less than 25° F a systematic HMA compaction test is not required unless, an area shows signs of visual pavement irregularities, surface segregation or a significantly different texture.

5. Determination of Systematic Density Testing Locations

Use either and infrared camera or a handheld non-contact infrared device to locate temperature differential areas as follows:

5.1 Infrared Camera

a. Delineate a 500 ft section of pavement and systematically check the area for temperature differentials within one minute of HMA placement and prior to any compaction of the pavement.
b. No temperature profiles shall be performed within the first or last 25 tons of production each day or within 25 feet of any transverse joint.
c. Focus the camera on the freshly placed HMA pavement prior to compaction. Adjust the camera to show the high and low temperatures.
d. Viewing should occur from the side of the paved lane approximately 15 to 20 feet back from the paver looking toward the paver.
e. The “spot” function on the camera should be used to obtain the temperature of the cool area and the surrounding HMA to assess for temperature differentials.
f. If the temperature differential is 25° F or more, locate the approximate center of the temperature differential area with the camera. The offset is from the center of the temperature differential area to the edge of the lane. Mark the location to be tested for systematic HMA compaction by placing a paint mark at the edge of the lane corresponding to the center of the temperature differential. Record the HMA surface temperature, temperature differential, offset, and station on DOT form 350-170 and in the MATS database.
g. If the temperature differential is less than 25° F, there is no need to mark the location unless an area within the paved lane has a significantly different texture. If testing is performed because of a significantly different textured area, locate the center of the

affected area and mark the location as described in step g and as shown in Figure 1 with an (S) after the temperature differential.

5.2 Handheld Noncontact Infrared Device

a. Delineate a 500 ft section of pavement and systematically check the area for temperature differentials within one minute of HMA placement and prior to any compaction of the pavement.

b. No temperature profiles shall be performed within the first or last 25 tons of production each day or within 25 feet of any transverse joint.

c. Perform a longitudinal scan of the pavement by standing at the edge of the paving lane about 5 to 10 feet back from the paver. Scan the mat with the handheld noncontact thermometer continuously in a longitudinal manner by walking behind the paver in the direction of paving, staying the same distance away from the paver for 500 ft of HMA placement.

d. The offset for the longitudinal profile should be anywhere from 18 inches from the edge to no more than half the width of the paved lane. (The need to vary the longitudinal offset will be necessary to get an accurate representation of the whole mat.) Scanning temperatures for the other half of the paved lane should be performed from the other side.
Note: Typically, temperature differentials or surface segregation can be captured with the longitudinal scan.

e. Perform a transverse scan after completion of the longitudinal scan, making sure to scan the entire width of the paved lane excluding the outer 18 inches on each side. It should be performed approximately 5 to 10 feet behind the paver (to check for streaking of the mat).
Note: Typically, streaking caused by temperature differentials or surface segregation will be captured by the transverse scan.

f. If the temperature differential is 25° F or more, locate the approximate center of the temperature differential area by scanning that specified location. The offset is from the center of the temperature differential area to the edge of the paved lane. Mark the location to be tested for systematic density testing by placing a paint mark at the edge of the lane corresponding to the center of the temperature differential. Record the HMA surface temperature, temperature differential, offset, and station on DOT form 350-170 or in the MATS database.

g. If the temperature differential is less than 25° F, there is no need to mark the location unless an area within the paved lane has visual pavement irregularities, surface segregation or a significantly different texture. If testing is performed because of a significantly different textured area, locate the center of the affected area and mark the location as described in step g and as shown in Figure 1 with an (S) after the temperature differential.

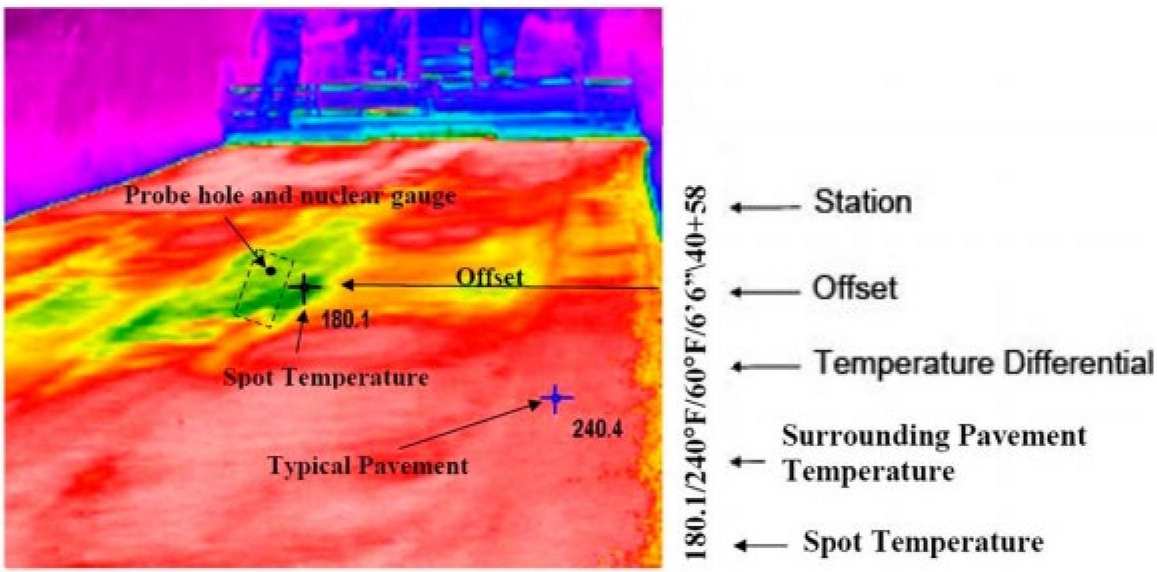
6. Systematic Density Testing Procedure

a. Systematic density testing shall begin after finish rolling is completed.

b. All systematic density testing shall be performed in accordance with WSDOT FOP for WAQTC T 355.

c. Systematic density testing shall be performed at all the locations recorded in 5.1f and 5.2f of this procedure. Gauge probe shall be placed at the station and offset determined above as the center of the temperature differential area.

e. If any temperature differentials are found in the initial assessment of the paving operations, at least one temperature profile shall be taken for every subsequent 500 ft of paving operation.
d. If no temperature differentials or streaks greater than 25° F are found or if there are no more than 2 density readings lower than 90 percent found in a 500 ft section, the testing frequency may be reduced. Random checks however, should continue to be made throughout the day and the results recorded.
e. If any significant equipment or weather changes occur, temperature profiles should be performed to determine if the new operation is capable of producing uniform HMA temperatures.
f. If it is found that the paving machine is creating areas that are significantly different in texture from the surrounding pavement, systematic density tests should be performed to determine if these are areas of low cyclic density.



Marking Location of Temperature Differential
Figure 1

https://wsdot.wa.gov/publications/manuals/fulltext/M46-01/t355.pdf

WSDOT Errata to FOP for AASHTO T 355
In-Place Density of Asphalt Mixtures by Nuclear Methods

WAQTC FOP for AASHTO T 355 has been adopted by WSDOT with the following changes:

Material

Filler material: Not used by WSDOT, unless SMA is being placed, then use filler material as described.

Test Site Location

Replace step 1 with below:

1. WSDOT requires test location selected per WSDOT Test Method 716.

Procedure

Method A – Average of two one-minute tests - *Not recognized by WSDOT use Method B:*

APPENDIX – CORRELATION WITH CORES

Correlation with Cores

Replace step 2 with below:

1. Obtain a pavement core from each of the test sites according to WSDOT SOP 734. The core should be taken from the center of the nuclear gauge footprint.

IN-PLACE DENSITY OF ASPHALT MIXTURES BY NUCLEAR METHODS FOP FOR AASHTO T 355

Scope

This test method describes a procedure for determining the density of asphalt mixtures by means of a nuclear gauge using the backscatter method in accordance with AASHTO T 355-18. Correlation with densities determined under the FOP for AASHTO T 166 is required by some agencies.

. . . (Method has no information/criteria on segregation)

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