Evaluation of Longitudinal Joint Density Specification on 2012 Polymer Modified Warm-mix Asphalt Projects in Connecticut

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Connecticut Transportation Institute
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Acknowledgments

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Standard Conversions

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 yard	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 degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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	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	35.314	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 degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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16. Abstract

In order to examine performance and establish future longitudinal joint density requirements on projects using Polymer Modified Asphalt (PMA) and Warm Mix Asphalt (WMA), this study examines test data from several pilot projects that were constructed during the 2012 construction season on limited access highways in Connecticut. The current requirement for in-place longitudinal joint density on non-WMA/PMA projects is 91.0 percent of maximum theoretical density. A major focus of this study was to determine if that requirement was achievable using PMA. Inspection of the project during construction revealed no indications of issues that may have contributed to lower in-place density. Core samples of the bridge deck and roadway longitudinal joints were collected from the projects and specimens analyzed. Based on these results, it is recommended that the specification for joint density on pavements using WMA/PMA asphalt remain at 91.0 percent for roadway lots. The dataset from bridge deck joints is insufficient to make any recommendations.

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Executive Summary

The Connecticut Department of Transportation (ConnDOT) initiated a warm mix asphalt (WMA) project during the 2011 construction season that included the use of polymer modified asphalt (PMA) on a multi-lane section of interstate highway. The requirement for longitudinal joint density on that project was 91.0 percent of maximum theoretical density. It was observed during construction that after a short period of time, the mix stiffened to the point where there was no additional benefit from continued compactive effort, and the contractor was not able to meet the longitudinal joint density requirement. It is likely that the cause of this was the addition of a Styrene Butadiene Styrene **(**SBS) polymer to the asphalt. It was speculated that the typical requirement of 91.0 percent of maximum theoretical density on longitudinal joints using warm mix asphalt with polymer modified asphalt (WMA/PMA) may not be reasonable. It was believed that reducing the requirement to 90.0 percent of maximum theoretical density on WMA/PMA projects may be more reasonable, and might not affect the quality of the longitudinal joint because the negative effects of the lower density of the longitudinal joints may be compensated for by the improved cracking and fatigue resistance that the SBS polymer has on the pavement.

In an effort to make this determination, and to make recommendations on the specified level of compaction in the region of the longitudinal joint on WMA/PMA projects, several more of these projects were monitored and analyzed during the 2012 construction season. The minimum density level specified for these projects was 90 percent, lowered from the typical 91 percent. The research team was on hand during construction to verify that there were no construction related issues. The research team also collected the cores, which were cut for potential permeability testing in the laboratory. The research team then obtained all of the official longitudinal joint density measurements from ConnDOT. Observation of the placement on the projects gave no indication that there were any construction related issues that may negatively affect the density at the joint. Review of the density results indicate that 91.0 percent of maximum theoretical density is reasonably achievable and should not be lowered to 90.0 percent for roadway lots. The research team does not feel there is a large enough dataset to make conclusive recommendations as to the specified level of density on bridge decks.

A review of regional specifications for density levels on longitudinal joints was also conducted. The reviewed regional specifications showed that none of the surrounding states DOTs specify a density level at the longitudinal joint. Several of them indicated that cores are not to be cut within a certain distance from the longitudinal joint.

Introduction and Background Summary

Longitudinal joints in asphalt pavements, both hot mix asphalt (HMA) and warm mix asphalt (WMA) are formed where the edge of the completing pass of the paver meets the edge of the previous paver pass. Given traffic maintenance issues, it is common practice to pave one lane, compact it and then switch traffic onto that lane, and pave the next lane. This means that there is hot material being compacted against previously paved cold material to form the longitudinal joint. Because of this temperature difference and reduced thickness where the joint material is compacted, it is common that density levels in the joint region of the pavement are lower than the surrounding mat. This combined with the expansion and contraction of asphalt pavements resulting from daily temperature cycling causes these joints to have a tendency to fail (Figure 1).

Figure 1. Longitudinal Joint Opening

The infiltration of water into the resulting longitudinal crack can accelerate the deterioration of the pavement, especially during colder times of the year. From a safety perspective, pavements where the longitudinal joints have a significant opening, pose a potential danger to bicyclists as well as motorcyclists, particularly if the width of the opening at the longitudinal joint approaches or exceeds the width of the tires. When longitudinal joints have failed and opened up significantly, costly maintenance must be performed, which can include patching, crack sealing/filling and in some cases, milling off and replacing the wearing surface even if the rest of the pavement is performing well.

To prevent or reduce these premature failures special attention must be paid to the construction of longitudinal joints. It is imperative that enough material be placed at the joint location, and that the joint itself is compacted to an adequate level of density. It is the current practice in Connecticut to construct longitudinal joints with a notched wedge (Figure 2).

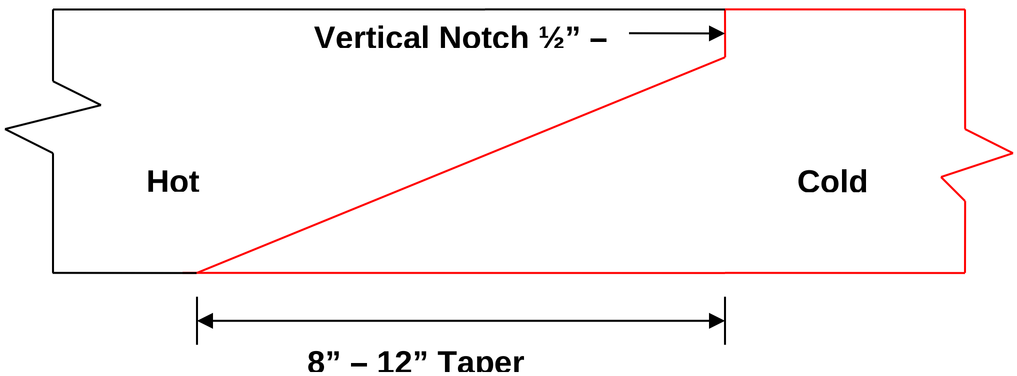

Figure 2. Notched Wedge Joint Diagram

This practice, when performed correctly, can aid in construction expedience since vehicles can traverse these open joints much more efficiently than with vertical or butt joints. The notched wedge also assists in achieving adequate levels of compaction [1].

The Connecticut Department of Transportation (ConnDOT) initiated a WMA project during the 2011 paving season, which included the use of polymer modified asphalt (PMA) on a multi-lane section of Interstate Highway. The requirement for longitudinal joint density on that project was 91.0 percent of maximum theoretical density (MTD). It was observed during construction of that project that after a short period of time, the mix stiffened to the point where there was no additional benefit from continued compactive effort. It is likely that this resulted from the effect of the addition of polymer to the asphalt. In any case, the contractor was not able to meet the longitudinal joint density requirement on that project. It is speculated that the requirement of 91.0 percent of maximum theoretical density on longitudinal joints using warm mix asphalt with Polymer Modified Asphalt (WMA/PMA) may not be reasonable. It is further speculated that reducing the requirement to 90.0 percent of maximum theoretical density on PMA projects may be a more reasonable objective, and might not have a negative impact on the quality of the longitudinal joint so long as the 90.0 percent requirement is met. It is believed that the negative effects of the slightly lower density in the area of the longitudinal joints may be (partially or entirely) offset by the effects of the addition of the Styrene Butadiene Styrene (SBS) polymer to the asphalt binder.

Problem Statement

The level of compaction in the region of the longitudinal joint on WMA/PMA projects needs to be reasonably specified. This specified level of compaction should be achievable during construction and align with the requirement for ensuring structural integrity of the entire pavement system.

Objectives and Work Plan

There were five resurfacing projects that incorporated the use of WMA/PMA scheduled for the 2012 ConnDOT construction season. Based on the experience from the 2011 WMA/PMA project previously discussed, the longitudinal joint density specification was adjusted such that 90.0 percent of maximum theoretical density was the requirement for those 2012 WMA/PMA resurfacing projects. The exact protocol is illustrated below in Table 1, which was extracted from Table 4.06-10 from the Special Provision for Warm-Mix Asphalt Projects in the ConnDOT Standard Specifications [2]. This special provision has been updated for subsequent paving seasons, since the generation of this table for the 2012 construction season.

Table 1. Longitudinal Joint Density Specification

Average Core Result Percent Density (ACRPD)	Percent Adjustment for non-bridge lots (1,2)	Percent Adjustment for bridge lots (1,2)
96.1 – 100.0	+5.0 – 2.5*(ACRPD – 96.0)	+5.0 – 2.5*(ACRPD – 96.0)
93.0 – 96.0	+5.0	+5.0
90.0 – 92.9	+(5/3)*(ACRPD – 90.0)	+(5/3)*(ACRPD – 90.0)
88.0 – 89.9	-15.0*(90.0 – ACRPD)	-15.0*(90.0 – ACRPD)
87.0 – 87.9	-30.0	-50.0
86.9 or less	Remove and Replace	Remove and Replace

(1) ACRPD = Average Core Result Percent Density
(2) All Percent Adjustments to be rounded to the second decimal place. For example, 1.6667 is to be rounded to 1.67

The main objective of this research was to ensure adequate performance of longitudinal joints constructed with WMA/PMA on those five resurfacing projects during the 2012 construction season, and to determine if the specified level of compaction at the joints needs to be adjusted. The tasks to accomplish this objective were:

- Perform review of literature from agencies and organizations with experience on this topic. This includes a review of pertinent specifications of other regional transportation agencies, as well as published reports from both agencies and academia
- Monitor the construction of longitudinal joints on all five of the WMA/PMA projects constructed during the 2012 season
- Obtain longitudinal joint density values from ConnDOT for all monitored projects
- Perform laboratory testing of cores cut from longitudinal joints on 2012 resurfacing projects. This consists of laboratory permeability testing and comparison analysis of obtained density information
- Make specification recommendations based on results of performed work, which includes observations made during the construction of the longitudinal joints that appear to have either a positive or negative impact on the joint density

Review of Regional Specifications

Upon review of regional longitudinal joint specifications, it became evident that requirements specifically for WMA/PMA joint applications were generally not detailed by the agencies. The general longitudinal joint specifications for each agency are summarized below.

Rhode Island Department of Transportation (RIDOT)

RIDOT [3] states that the placement of asphalt pavement must be as continuous as possible, that joints must be constructed in a careful manner. It is stated that the joints must be sealed and bonded. It is also required that longitudinal joints on successive layers of the pavement be staggered by at least six inches and the joint in the top layer be at a location in the vicinity of delineated travel lanes. Any hot bituminous material falling on the cold side of the mat must be raked to the joint itself in a manner that does not cause the material to be broadcast over the mat. It is required that a coating of asphalt emulsion be placed under the edge of a newly placed pavement.

New York State Department of Transportation (NYSDOT)

NYSDOT [4] offers the option to use either a butt joint or a tapered wedge joint. It is required that any exposed joint in excess of 100 feet that is to be left open until the next day be a tapered wedge joint.

The use of a butt joint requires the contractor to overlap the cold side of the joint by 2-3 inches when placing the hot side. Overlapped material is then required to be raked back to the hot side such that it can be compacted into the joint by the roller operator. Broadcasting the overlapped material over the mat is not allowed.

The use of the tapered wedge joint requires a ½ in. vertical step down (notch) from the surface. The slope of the wedge is to be no greater than 1in./8 in. Overlap of the hot side pass is to be 1 to 1 ½in. onto the cold side and then raked back to the hot side for compaction. Broadcast of the hot material over the mat is not allowed.

Section 402 of the specification has a 92-97 percent specification limits with a Percent within Limits (PWL) >93. There is no specific language about density requirements for longitudinal joints.

NYSDOT does not consider longitudinal density for acceptance determinations. In accordance with Materials Procedure 96-04 [5], density determination used for acceptance must be no closer than 0.6 meters from any designated edge.

Maine Department of Transportation (ME DOT)

ME DOT [6] requires that all joint cold sides be coated with emulsified asphalt as well as a 3-inch coating on the pavement that is being overlaid. This specification refers only to vertical joints. This requirement is waived in the event of echelon paving.

Longitudinal joint density is not monitored by the ME DOT. Cores cut for acceptance density testing are not allowed to be any closer than nine inches from the longitudinal joint [7].

Vermont Agency of Transportation (VAOT)

VAOT [8] requires that the paver be equipped with a wedge or notched wedge forming device. The slope of the plate shall be no steeper than 1 vertical inch over a 3 inch horizontal distance. Pavers are also required to be equipped with joint heaters, which will heat the cold side of the longitudinal joint (the wedge or taper) to a minimum of 95 degrees C prior to placement of the hot side material. It is also required that the longitudinal joint be compacted first, followed by compacting from the outside edge and proceeding towards the center. Density is required to fall within 92.5 percent and 96.5 percent of maximum specific gravity. VAOT requires that cores cut for acceptance determination of payment be cut no closer than six inches from a longitudinal joint. As such, there is no longitudinal joint density specification.

Massachusetts Department of Transportation (MassDOT)

MassDOT [9] requires that all joints be treated with hot poured rubberized asphalt sealer prior to the placement of the hot material that completes the formation of the joint. This requirement is only waived if echelon paving is taking place and the temperature of the cold side has not fallen below 95 degrees C prior to paving the hot side. There is no reheating of the joint allowed.

The density of the in-place pavement is required to be 95 ± 2.5 percent of maximum theoretical density. Core samples cut for acceptance are not allowed to be cut within 12 inches of an unconfined edge or within 12 inches of a longitudinal joint. Therefore, there is no longitudinal joint density specification.

New Hampshire Department of Transportation (NHDOT)

NHDOT [10] requires that when material is placed on the hot side, it shall be tightly crowded against the face of the abutting lane (cold side). Placement of the hot side is to overlap the cold side face by 1 to 2 inches. Compaction at the joint is to be accomplished by first rolling to within six inches of the joint interface and then overlapping the cold side by six inches. Any further necessary compaction takes place during intermediate and finish rolling. There is a minimum requirement of 92 percent of maximum theoretical density on paving projects, as well. Cores are not allowed to be cut within one foot of any break in pavement slope or pavement edge. There is no specific requirement for density along the longitudinal joints.

Construction Monitoring

CAP Lab personnel were present for the monitoring of construction of four of the five WMA/PMA projects constructed during the 2012 construction season. The four projects that were monitored are listed in Table 2, in no particular order.

Table 2. Monitored Projects

Project #	Route #	Town/Area
42-312	I-84	East Hartford/Manchester
57-117	I-395	Griswold
145-103	I-84	Union
96-199	I-84	Middlebury/Newtown/Southbury

Monitoring involved coordinating with project foremen, as well as Quality Control personnel and ConnDOT personnel, to identify any problems encountered during production and placement of the material. Thermal images were taken periodically to ensure temperature uniformity, as well.

Collection of Pavement Cores

The research team requested transfer of as many of the pavement cores as possible on each of the four projects to the CAP Lab. These cores would be used for testing of permeability with a laboratory permeameter. Over the course of a few months, following the construction of these projects, the cores were obtained by the CAP Lab.

Permeability Testing of Collected Cores

The intention of permeability testing of the cores was to determine if there was in fact, a significant difference in permeability among cores that registered closer to 90.0 percent of maximum theoretical density versus those registering closer to 91.0 percent. The test method used was ASTM Provisional Specification (PS) 129-01 [11]. The basic process is to allow a column of water in a standpipe to run through a compacted specimen that is initially vacuum saturated. The saturated specimen is situated within the flexible wall chamber. The standpipe cover assembly is then inserted over the specimen and air pressure is applied around the flexible membrane to create a seal between the sides of the core and the membrane. This is done to preclude the movement of water around the core, as opposed to through it. The level of the water column in the stand pipe is then measured over time. The rate of flow of water through the specimen and the thickness of the specimen are used to compute the coefficient of permeability via Darcy's Law. Figure 3 shows the setup of the laboratory permeameter.

Figure 3. Laboratory Permeability Assembly

Although the provisional specification was discontinued in 2003, it was the intention of the research team that if consistency and continuity could be established among the permeability data, then relative comparisons could be made.

Section 8.5 of the PS 129 test method states that three individual diameter measurements shall not vary by more than 5 mm and, that the minimum diameter of the roadway cores be 150.0 mm. Unfortunately, on average, the cored specimens were between 143.0 and 144.0 mm. This is likely a product of the cores being cut with a bit that measures less than 150.0 mm on the inside diameter. An attempt to measure permeability of the received cores was made, in any case. During testing of the cores it was very clear that a complete seal could not be established between the flexible chamber wall of the permeameter and the sides of the cores, even when air pressure was set much higher than the test method prescribes. Multiple trials on multiple cores proved this to be the case. The water in the standpipe ran around the sides of the cores in most cases. Because of this, there was no continuity in the results in any of the flow measurements that were attempted.

Density Analysis of Longitudinal Joint Cores

All of the ConnDOT density results for the four projects were examined by the research team. Results were compiled and the average longitudinal joint density for those projects is shown graphically in Figure 4.

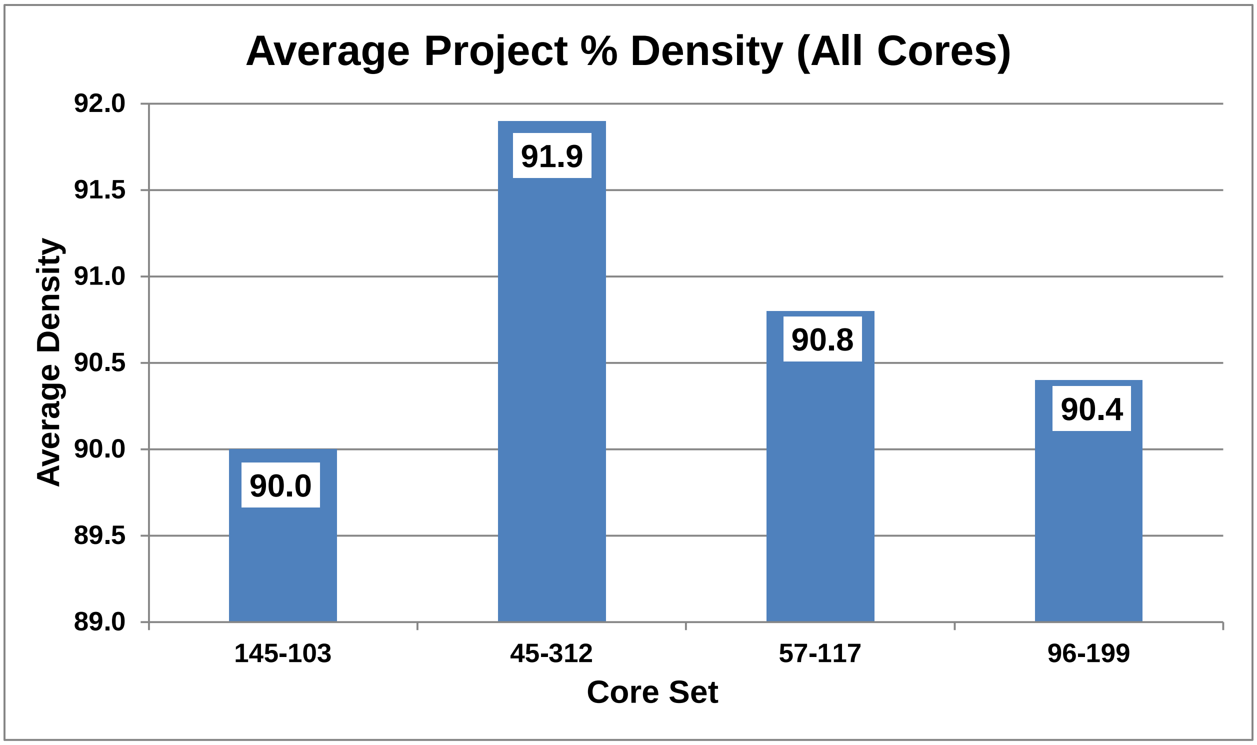

Figure 4. Average Joint Density All Cores

Of note is that ConnDOT specifications do not permit vibration or oscillation of the HMA compaction equipment on bridges. Projects 57-117 and 96-199 had a significant number of cores that were cut on bridges. When the cores that were cut on bridges are removed from the data set, those two projects contain an overall increase in longitudinal joint density. The average joint density with the bridge cores excluded for each of the four projects is shown in Figure 5.

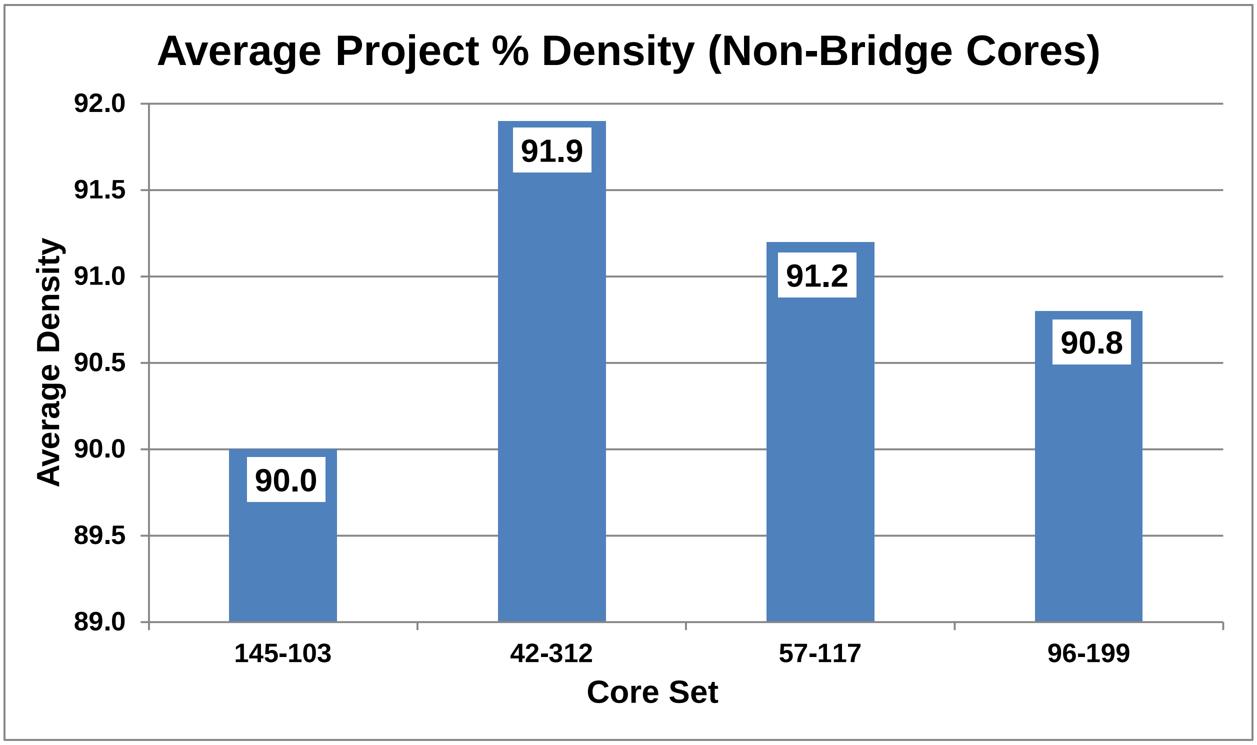

Figure 5. Project Joint Density (Non-bridge Cores)

Projects 57-117 in Griswold, CT and 96-199 in Middlebury/Newtown/Southbury, both experienced an overall increase in density of 0.4 percent on longitudinal joint cores when the bridge cores were removed from the data set. Furthermore, the average joint density on project 57-117 goes from below 91.0 percent to above 91.0 percent when the bridge cores are excluded from this analysis. Project 96-199 goes from 0.6 percent below the 91.0 percent threshold to within 0.2 percent of that threshold when bridge cores are removed. It should also be noted that project 145-103 was smaller in size than the other projects. The number of cores per project is shown in Table 3.

Table 3. Number of Joint Cores Per Project

Project	Non-Bridge Cores	Bridge Cores	Total Cores
145-103	37	0	37
42-312	115	0	115
57-117	89	32	121
96-199	96	31	127

As seen in Table 3, Project 145-103 produced 37 cores, which represents only 11 percent of the total cores from the projects. Therefore, the influence that the small sample of cores from Project 145-103 has on the overall longitudinal joint density numbers is relatively minor as compared to the other three (3) projects, which all had higher overall average joint density values in addition to the substantially higher number of cores. This is illustrated in Figure 6, where it can be seen that the overall core density and non-bridge core density averages both register higher than the average density on Project 145-103.

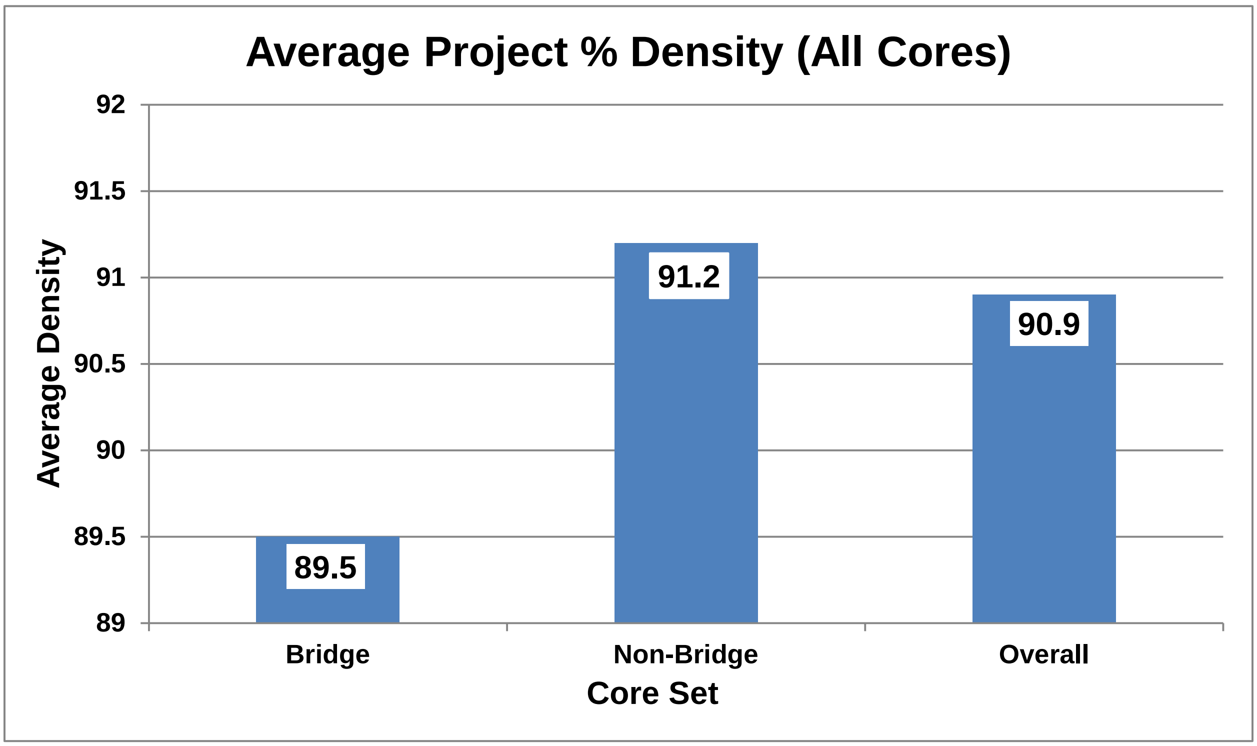

Figure 6. Average Density (Bridge, Non-Bridge, Overall)

In addition to the analysis of the average density values, the research team looked at the percentage of cores that registered both above and below 91.0 percent of maximum theoretical density on non-bridge cores. A frequency distribution of the density values is shown graphically in Figure 7, and the breakdown of the basic descriptive statistics is shown in Tables 4 and 5. The 91.0 percent density percentile was 43.70 percent, meaning that 43.70 percent of all of the non-bridge core densities were less than 91.0 percent of maximum theoretical density.

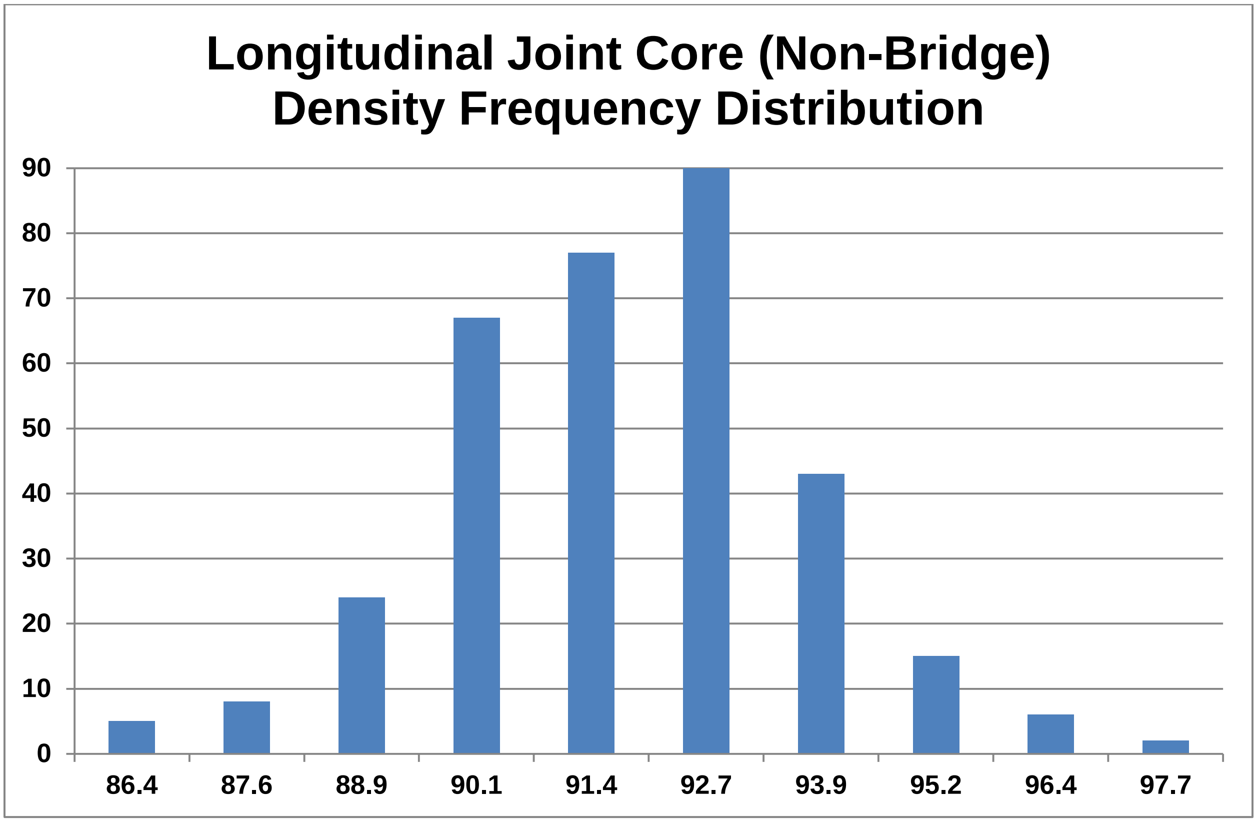

Figure 7. Frequency Distribution of Non-Bridge Joint Core Density

Table 4. Non-Bridge Core Density Standard Deviations

Project	Standard Deviation	# of Cores
43-112	2.06	115
145-103	1.62	37
57-117	1.72	89
96-199	1.79	96
Overall	**1.95**	**337**

Table 5. Non-Bridge Core Density Standard Deviations

Quartile	Density (% MTD)
Q0 (minimum)	85.11
Q1 (25th percentile)	89.86
Q2 (median)	91.22
Q3 (75th percentile)	92.45
Q4 (maximum)	97.61

Conclusions and Discussion

A review of regional specifications reveals how agencies feel the best joint density could be attained, as outlined in the different joint construction policies; however none included a longitudinal joint density level requirement.

It is stated in the Problem Statement, the specified level of compaction should align with both the requirement for sustaining the structural integrity of the pavement system, as well as what is reasonably achievable in the field during construction. It is too early at the current time to determine if the specified level of compaction is adequate for sustaining structural integrity as these surfaces are only two years old.

No insight could be gained from laboratory permeability testing of the collected cores since a seal was not attainable between the latex and the sides of the cores during the test. As such, no conclusions can be drawn about a difference in permeability among cores that register near 90.0 percent of maximum theoretical density versus those registering closer to 91.0 percent.

After review of the testing data, which included 400 longitudinal joint core densities on four different WMA/PMA construction projects, there are numerous conclusions and they're as follows;

In light of Figures 4 and 5 and Table 3, the reader should be made aware of the lowered significance of the contribution from Project 145-103 relative to the other three projects. The number of cores on Project 145-103 was less than 10 percent of the total number of cores that were analyzed for this research. There were no bridge cores taken from Project 145-103. When the 37 cores from that project are removed from the dataset, the overall non-bridge average density rises just 0.1 percent, from 91.2 percent to 91.3 percent. The reader should keep in mind this small sample size when looking at the density averages for all of the individual projects.

When viewing the average project density from all of the projects on an individual basis, such as in Figure 4, it may appear that 91.0 percent overall on longitudinal joints is not reasonably attainable, as only one of the four projects met that criteria. As stated previously, ConnDOT does not allow the use of vibration of rollers on bridges during compaction. When viewing the bridge and non-bridge core density data separately, as seen in Figure 6, it becomes readily evident that the density measured on the bridges has an overall negative impact on density averages. Figure 6 shows that the non-bridge average longitudinal joint density for all four projects increases to 91.2 percent of maximum theoretical density if the bridge cores are not considered. This, combined with a median value of 91.2 percent as seen in Table 5 implies that a longitudinal joint density requirement of 91.0 percent of maximum theoretical density on WMA/PMA non-bridge lots is achievable and realistic.

Bridge core densities were analyzed for just two of the four projects. In total there were 63 core density values analyzed for the bridge lots. As shown in Figure 6 and based on the number of cores analyzed, 91.0 percent of maximum theoretical density for pavement longitudinal joints placed on bridges was not achieved, and would require a larger dataset to fully analyze the density requirements for bridge joint density requirements.

Recommendations

Based on the discussion above, the research team makes the following recommendations regarding the specification of longitudinal joint density levels on WMA/PMA resurfacing projects:

- Statistical lots for longitudinal joint density on WMA/PMA projects should continue to separate bridge cores and non-bridge cores

- Longitudinal joint density specifications for non-bridge lots should require a minimum average of 91.0 percent of maximum theoretical density for full payment

- The projects analyzed for this research should continue to be monitored for any deterioration of the longitudinal joints in the future. This could be done during the annual ConnDOT pavement assessment

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