Hot Mix Asphalt Research Investigation for Connecticut

Study No: SPR-2250

Final Report – Part G

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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)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°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	poundforce per square inch	6.89	kilopascals	kPa

Technical Report Documentation Page

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16. Abstract
Six topics were investigated involving specifications, performance and testing of hot mix asphalt in CT. An investigation into the possible reduction in the number of mix design levels used in CT resulted in a recommendation to eliminate Level 4. An investigation into minimum asphalt contents in CT mixes was halted and commenced under a different project. An investigation into permeability/porosity testing in CT concluded that permeability can serve as a surrogate for density but a larger, more robust dataset is needed to validate regression models that could be used on mixes in CT. An investigation into the use of a field permeameter for non-destructive dispute resolution testing on bridge decks concluded that the test is too subjective to be used in that manner. Comparisons between wearing surfaces designed with Superpave and Marshall methods indicated no difference in performance as it relates to resisting damage from environmental or loading stress.

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1.0 Executive Summary

The research conducted for SPR 2250 covered a broad range of topics relating to testing and specifications for hot mix asphalt (HMA) in Connecticut. In 2006, the ConnDOT HMA Task Force Executive Committee identified areas of need, and a decision was made to combine them into one comprehensive research project with multiple focal points. The research focused on the following six topics:

- A. Reduce the Number of Superpave Mix Design Levels
- B. Develop Guidelines for Minimum Asphalt Content
- C. Research Permeability/Porosity Testing of HMA Mix Designs
- D. Evaluate Permeability as Dispute Resolution for Bridge Deck Density
- E. Investigate Whether Premature Cracking is More prevalent in Certain Superpave Mixtures
- F. Modify ConnDOT Databases to Process HMA Test Data for Statistical Validation

Individual final reports were published previously for each topic. See Appendix A for the report titles for Topics A through E.
Part A. This work involved HMA performance testing conducted on laboratory specimens along with an examination of mix design constituent requirements for the different Superpave mix design levels. The recommendation was made to eliminate the Traffic Level 4 Mix design requirement and replace with Level 3 along with an elastomeric polymer modified asphalt in areas where permanent deformation is a concern. The recommendation was also made to maintain the Traffic Level 1 mix in an effort to accommodate the needs of Connecticut municipalities.

Part B. At the time this research work was performed by the CAP Lab, HMA specification changes were made by CTDOT. These specification changes ultimately rendered the work that was being done and the research results of this project to be inconsequential. A later study was conducted examining this topic and the reader is referred to *CT-2286-F-18-5, "ConnDOT Specification Requirements for Minimum Asphalt Requirements."*

Part C. This research involved field and laboratory testing of HMA mixes in Connecticut. A strong relationship was demonstrated between permeability and density and this can be modeled with reasonable accuracy. In order to use permeability as a surrogate for density, a much larger dataset would need to be examined so the regression models can then be validated and calibrated for mixes in CT.

Part D. This research investigated the use of a falling head permeameter for dispute resolution on bridge decks. Making accurate falling-head permeability measurements in the field is challenging because the instrument operator must be sure there are no leaks around the seal, and timed visual falling head measurements can be subjective. Given these challenges, considering the level of subjectivity, the research team concluded that using the permeameter had the potential to trigger more disputes than it would solve.

Part E. This research involved comparisons between Superpave wearing surfaces and surfaces designed via the traditional Marshall method that were placed under similar conditions, on similar highway sections and during the same time frame (2001 – 2003). Examinations involved site visits to identify the presence of any distress/deterioration. Photolog imagery and yearly Pavement Serviceability Ratings conducted by CTDOT personnel were also utilized for the comparison. The comparisons showed no difference in the performance of the different surface types for either dynamic loading or environmental stresses.

Part F. During the course of the research that took place under SPR-2250, this task was removed from the work plan with mutual agreement between CTDOT and UCONN.

Part G. Prepare Final Report, Executive Summary and Presentation. The publication of this final report fulfills the final task for the conclusion of this SPR-2250 research project.

2.0 Introduction and Background Summary

Hot mix asphalt (HMA) pavement is used as the wearing surface on most roadways in Connecticut. Ensuring that the HMA performs well for as long as possible is important as financing to replace these wearing surfaces is becoming harder to secure. It is deemed critical to match roadway life with funding mechanisms, such as for example, Special Transportation Obligation Bonds, to maintain a solvent-viable paving program.

The Connecticut Department of Transportation's HMA Task Force's Executive Committee identified several issues that required additional research. These topics included:

- Reduce the Number of Superpave Mix Design Levels
- Develop Guidelines for Minimum Asphalt Content
- Research Permeability/Porosity Testing of HMA Mix Designs
- Evaluate Permeability as Dispute Resolution for Bridge Deck Density
- Investigate whether Premature Cracking is more prevalent in Certain Superpave Mixtures
- Modify Current ConnDOT Databases to Process HMA Test Data for Statistical Validation

While these topics seemed to be very different, the research needed to answer the questions overlapped between the topics. Therefore, it made sense to group these topics together under a single research project.

At the outset of this research, Superpave had four (4) HMA mix design levels for each nominal maximum aggregate size. The Superpave mix design levels each corresponded to a range of traffic levels. This required each production plant supplying HMA in Connecticut to accommodate at least 12 mix designs, as Connecticut typically uses three (3) nominal maximum aggregate size HMA mixes. Prior to Superpave, most Connecticut HMA mix plants only had three (3) primary mix designs: Class 1, Class 2 and Class 4.

As these different mix designs may have required a different aggregate structure, it was difficult for the mix plants to shift production between the various mixes and consistently meet the Superpave volumetric requirements. This reduced the producers' ability to meet their customers' needs as it was difficult for the mix plant to rapidly change between the various mixes. In some instances, mix plants had been able to design Superpave mixes that meet the Superpave requirements of multiple design levels by using the same aggregate structure and adjusting the asphalt binder content.

The Superpave Mix Design System, to this day, does not put any limitations on the asphalt binder content so long as the mix meets volumetric requirements. However, the asphalt binder content of the mix has an effect on the long-term performance of the pavement: too little asphalt binder causes the pavement to be susceptible to premature cracking and raveling; too much asphalt binder or the incorrect Performance Grade of the asphalt binder causes the pavement to be susceptible to rutting and shoving. Some regional State Agencies had been concerned about this as many of the Superpave mixes had the appearance of being "dry" – meaning that there was not enough asphalt binder in them. This concern has led several agencies to require minimum asphalt contents to ensure adequate asphalt binder.

The advent of Superpave stressed the importance of stone-to-stone contact within the HMA pavement to resist permanent deformation. The desire for stone-to-stone contact led to HMA mixes that contained more coarse aggregate than the conventionally designed Marshall mixes. There were concerns that the decrease in fine aggregates in the Superpave mixes were resulting in an increase in the permeability of the pavement. The concern about permeability of the pavement was increased when water was observed seeping out of a new pavement at the base of a hill 24-36 hours after the precipitation event had ended.

One of the largest factors that affect the durability of an HMA pavement, is the in-place air void content of the pavement. At the outset of this research, ConnDOT specifications required in-place air voids to be measured using a nuclear density gauge. At the time of this research, ConnDOT had recently adopted a dispute resolution procedure for in-place air voids that involved measuring the density of cores cut from the compacted roadway. Cutting cores on the main line pavement did not present many problems, however, cutting cores on bridge decks was/is problematic as this runs the risk of damaging the waterproofing membrane, which is used on most Connecticut bridges. Damaging the bridge deck membrane would allow salt laden water easy access to the bridge deck concrete. This would increase the chloride content of the concrete and in turn increase the chances that the reinforcing steel would corrode at an accelerated rate.

It had been noted (prior to the onset of this research) by the ConnDOT Office of Maintenance that some Superpave pavements had been cracking sooner than the conventionally designed Marshall mixes that were previously used by ConnDOT. An investigation into whether premature cracking was more prevalent in Superpave mixtures was merited.

This Final Report (Objective and Research Task Part G.) summarizes all of the work that was done for each topic as part of this research project.

3.0 Problem Statement

At the time of this research, beginning in 2006, the transition to Superpave designed asphalt pavements in Connecticut from conventionally designed Marshall mixes was nearly complete. As this transition occurred, there were several issues that had arisen. These issues required additional research in order to provide information and hard data allowing ConnDOT to determine if changes to their specifications were warranted.

4.0 Objectives

Part A - Reduction in the Number of Superpave Mix Design Levels

The objective of Part A was to determine if the number of Superpave Design levels used in Connecticut could be reduced without compromising the performance of the pavement with respect to permanent deformation.

Part B - Develop Guidelines for Minimum Asphalt Content

The objective of this portion of the research was to determine if the then-current minimum asphalt binder contents used by ConnDOT were appropriate to improve the long-term performance of HMA pavements by increasing their durability while still being able to resist permanent deformation.

Part C - Permeability/Porosity Testing of HMA Mix Designs

The objective of Part C of this research was to determine if the then-current Superpave mixes used in Connecticut limited the permeability of the pavements to values suggested in the literature.

Part D - Evaluate the Feasibility of Using Permeability for In-place Density Dispute Resolution on Bridge Decks

The objective of this work was to determine if measuring the permeability of a pavement on a bridge deck would work as a non-destructive dispute resolution for the in-place density of the pavement.

Part E – Compare Field Performance of Superpave and Traditional Mixtures

The objective of Part E of this research was to study Superpave pavements that were reported to be aging/cracking more quickly than other Superpave mixes and conventional pavements designed using the Marshall Mix design method.

Part F - Modify ConnDOT Databases to Process HMA Test Data for Statistical Validation

The objective of Part F of this research was to enhance the handling of HMA test data to allow for statistical analysis, including having an ability to analyze Percent Within Limits (PWL)for Acceptance purposes.

Part G – Prepare Final Report, Executive Summary and Presentation

The objective of Part G for this research project was to produce a final report that summarized the work performed, findings and recommendations for each part of the project. An Executive Summary and presentation were also included in this part of the project.

5.0 Final Report Structure

Each task/part associated with this research culminated in its own final report. These final reports were submitted to the ConnDOT for approval following the completion of that portion of the research. As such, this Final Report consists of five (5) individual summaries of those Final Reports that were generated and approved following the completion of that specific part.

Part A. Reduction in the Number of Superpave Mix Design Levels

Part A. Background and Summary

The Superpave mix design system was developed as part of the Strategic Highway Research Program during the early 1990's. One of the primary foci of the Superpave mix design system was to eliminate the problem of permanent deformation of Hot-Mix Asphalt (HMA) pavements as many transportation agencies were having problems with permanent deformation issues. This permanent deformation was most commonly observed as rutting in the wheel paths. The Superpave mix design system stresses the importance of stone-on-stone contact to allow the pavement to support the traffic loadings without actually deforming.

In order to address this problem, the Superpave mix design system increased the compactive effort applied to the HMA mixture in the Superpave gyratory as the anticipated traffic loadings increase. At the time of this research, the Superpave mix design methodology utilized four distinct traffic level bands corresponding to these traffic loadings. The effect of these four traffic levels was that each HMA production facility was required to have four different Superpave mix designs for each nominal maximum size of HMA they produced. For each HMA plant, this typically required a minimum of twelve different Superpave mix designs. Prior to the invention and adoption of the Superpave system, there was only a need for HMA plants during the 1990s to accommodate three commonly-used ConnDOT mix designs: Class 1, Class 2 and Class 4.

It is difficult for HMA producers to change between mixes with different aggregate blends (structures) in a timely manner to meet their customers' needs. In response to HMA producers needing at least twelve different Superpave mix designs, HMA producers have tried to develop their mix designs for the four different traffic levels with minimal differences to the aggregate structure. This resulted in some cases of the exact same aggregate structure being used for two different traffic levels with the only difference being the amount of asphalt binder being added to the mixture. Typically, the higher traffic level mixes had a lower asphalt binder content. It was generally accepted that as the asphalt content of HMA mixtures decreased, the pavement was less durable as it pertained to environmental damage.

With different traffic level mixes having the same, or similar, aggregate structure and decreasing asphalt binder contents as the traffic levels increased, there was some concern that the higher traffic level Superpave mixes did not provide any significant increase in the pavement's ability to resist permanent deformation, and may have actually decreased the ability to resist environmental damage, thus, ultimately decreasing the actual service life of the pavement structure.

Part A. Conclusions

While the sample sizes of materials tested may have been too small to be able to draw any firm statistical conclusions about the effects of the different traffic levels, it was possible to observe that there did not appear to be any significant differences between the performance of the different levels in the Asphalt Pavement Analyzer (APA) and Hamburg wheel-tracking tests. There were too many variables to consider when examining the different mixes with this small sample size. The number of samples required to capture all of the variables was quite large and it would not have been practical to conduct all of the testing.

The average rut depths observed with the APA test for all of the materials were minimal. Also, there was not a significant difference found in rut depth between Levels 2 and 4 These were positive signs that the Superpave mixes used in Connecticut were not prone to rutting and other forms of plastic deformation, and that the Superpave mixes in Connecticut are quite capable of withstanding loading from traffic.

The results from the Hamburg testing indicated that there were no significant differences in the Superpave mixes used in Connecticut. The analysis of this data was somewhat more complicated as there were two factors that affect the outcome of the test results, the number of cycles and the rut depth as well as the aggregate and asphalt binder interaction. Using the average rut depths for each level of mix did not capture what was occurring within each HMA production facility as there were several large test result differences that were influencing the overall average values. Therefore, it was more telling to compare the results for each of the plants individually. There were many instances where the lower level mixes required almost the same number of cycles to fail or actually more cycles to fail as compared to the next highest level. A similar comparison was made between Hamburg rut depths for each HMA plant. There were many instances when the lower level mixes had comparable rut depths as compared to the higher level mixes. Examining the data for each HMA plant for the Hamburg test results did not show any substantial differences between most mixes.

As most of the Superpave mixes for each HMA production facility utilized the same aggregates (at that facility) with little or no difference in the blending of them in the production of Superpave, it was not surprising that there was little difference between the performance of the Superpave mixes in the Hamburg and APA tests.

Part A. Recommendations

Based upon the results of the research and testing conducted as part of this project, the research team made the following recommendations:

- The use of Superpave traffic design Level 4 be eliminated for the purposes of the number of gyrations in the Superpave gyratory compactor as these mixes typically had the least amount of asphalt binder in them and yet the testing conducted did not show any significant difference in its ability to resist permanent deformation. The increase in asphalt binder content resulting with the use of Level 3, where Level 4 mixes had been used previously, was expected to improve the ability of the HMA to resist environmental damage..

- For areas that had a particular history of permanent deformation problems, it was recommended to use Level 3 mixes with an elastomeric polymer modified asphalt to mitigate those issues.

- When specifying Superpave mixes for roadways that were borderline between two levels, it was recommended that the lower Superpave traffic design level be specified.

- It was also recommended that the aggregate requirements remain unchanged for the various traffic design levels. This did not appear to present problems for most producers, as they tended to use the same aggregates to make the various levels of Superpave. It was suggested that it would benefit ConnDOT to review this possibility and its potential impacts internally as this seemed to be a viable alternative from the perspective of the research team.

- Superpave Traffic Design Level 1 should remain as part of ConnDOT's specifications even though it was rarely used by ConnDOT. Eventually, municipalities should be switching to Superpave and they will need the Level 1 mixes as they are the most resistant to environmental damage, which is typically the most damage experienced on low-volume roads.

- Additionally, it was recommended that some investigation be conducted to understand municipalities' reluctance to switch to Superpave and attempt to address the issues identified. It was the authors' belief that Level 1 Superpave mixes would benefit the municipalities' paving programs.

Part B. Develop Guidelines for Minimum Asphalt Content

Part B. Background and Summary

The correct quantity of liquid asphalt binder in a hot mix asphalt pavement plays a critical role in ensuring that the pavement lasts through its service life. If there is not enough binder in the mix then the binder will oxidize and become brittle faster and lead to premature distresses such as raveling and cracking. If too much binder is added to the mix then permanent deformation distresses such as rutting become prevalent.

The introduction and adoption of SuperPave HMA mix designs beginning in the mid to late 1990's lead to pavements that had a much higher quantity of coarse stone to combat rutting than mixes from earlier design methods. Coarser HMA mixes have reduced the total surface area of the aggregate in the mix. This decrease in surface area resulted in a situation where there was less binder necessary to completely cover the aggregate.

This research was initiated to investigate whether the proper amount of liquid asphalt binder in CTDOT HMA mixes was already being incorporated into them and/or if it was necessary to specify a minimum asphalt content. If the mixes used in Connecticut were not rich enough and a minimum binder content needed to be specified, then this research was also intended to investigate what level of binder content would be appropriate before rutting became a problem.

Part B. Conclusions and Recommendations

At the time this research work was performed by the CAP Lab, HMA specification changes were made by CTDOT. These specification changes ultimately rendered the work that was being done and the research results of this project to be inconsequential.

It was decided by the CTDOT and the research team that recommendations be made to end this research project and restart the work along new guidelines, with a new agreement and a strong technical advisory committee to investigate proper liquid binder contents and balanced mixes in Connecticut.

That endeavor was performed via another research project under SPR-2286 to which the reader is referred. The Final Report for that project is *CT-2286-F-18-5,"ConnDOT Specification Requirements for Minimum Asphalt Requirements."*

The literature review that was conducted as part of this research project was also relevant for and expanded on during the *SPR-2286* research. And so, for that portion of the research that was conducted as part of this work, the reader is also referred to *CT-2286-F-18-5*.

Part C. Permeability/Porosity Testing of HMA mix Designs

Part C. Background and Summary

The presence of water in asphalt pavements is detrimental to the life of the pavement. Most construction specifications require the pavement to be compacted to a specific air void content. As an asphalt pavement's air void content increases, the permeability of that pavement will typically increase. Therefore, measuring the air voids during construction is an indirect way to control the permeability for that pavement. Asphalt pavements with high permeability are vulnerable to binder oxidation and stripping of binder from aggregate (Mohammad et al. 2003; Mogawer et al. 2002). In addition to stripping, Allen et al. (2003) also indicated asphalt emulsification, frost heaving, and water emerging from lower pavement layers and then freezing at the surface were related to permeability. Many research studies have investigated methods to measure and quantify permeability to extend the life and durability of asphalt pavements. As a result, maximum permeability limits have been established for HMA pavements (Maupin, 2000). The objective of Part C of this research project was to determine permeability rates for current Superpave mixes used in Connecticut during that time.

Part C. Conclusions

The data collected and analyzed for this research indicated there was an exponential growth in permeability as the percent air voids increased. However, the regression models needed to be validated and calibrated before they could be used with any certainty. This procedure would require the collection of a large dataset for each mix type to ensure there were no abnormal permeability results. Furthermore, there was a strong relationship between density and permeability. This relationship can be modeled with reasonable accuracy and could be used as a surrogate for density. However, additional testing would be required to develop equations for each of Connecticut's HMA mixes and to improve the sample size (i.e., accuracy).

It appeared Connecticut mixes tested had a lower permeability than those reported in other published research. However, a larger sample size would be necessary to determine if this finding was true. Furthermore, the type of joint used in construction did not have a significant impact on the permeability of the joint. However, it should be noted that cores for the butt joints were not taken directly on the joint. These cores and permeability measurements were taken on the warm side of the joint. If the butt joints were cored directly on the joint, there is the potential the vertical seam between the two passes of the paver could serve as a weak point for water to flow through.

Part C. References

Mohamad L.., A. Herath, H. Baoshan. (2003). *Evaluation of Permeability of Superpave Asphalt Mixtures*. Transportation Research Record. **ISSN** 0361-1981. No. 1832. pp. 50- 58

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Maupin, G.W. Jr. *Asphalt Permeability Testing in Virginia.* Transportation Research Record, No. 1723, Part 2: Asphalt Mixtures. Paper No. 00-1206. Transportation Research Board, Washington D.C. 2000.

Part D. Evaluate the Feasibility of Using Permeability for In-place Density Dispute Resolution on Bridge Decks

Part D. Background and Summary

As also noted in the previous section, the presence of water in asphalt pavements is detrimental to the life of the pavement. Asphalt pavements with high permeability are vulnerable to binder oxidation and stripping of binder from aggregate (Mohammad et al., 2003; Mogawer et al., 2002). In addition to stripping, Allen et al. (2003) also indicated asphalt emulsification, frost heaving and water emerging from lower pavement layers and then freezing at the surface were related to permeability. In order to extend the life and durability of asphalt pavements, many research studies have investigated methods to measure and quantify permeability. As a result, maximum permeability limits have been established for Hot Mix Asphalt (HMA) pavements (Maupin, 2000). For bridge decks, density and permeability are an issue. At the time of this research, bridge deck pavements typically had lower densities due to the contractor's restriction from using a vibratory compactor on the bridge. At the time of this research, vibratory compactors were generally not used on bridges (and still are not to this day) due to fears of dynamic loading stresses and damage to the structure. The relationship between density and permeability indicated that the lower the density the higher the permeability. Pavement permeability can cause significant issues on bridge decks. For example, if steel reinforcing is exposed to water and salt permeating through the pavement, oxidation can occur and steel members will begin to deteriorate rapidly. Therefore, the objective of Part D of this research was to determine if measuring the permeability of a pavement on a bridge deck would work as a non-destructive dispute resolution test method for the in-place density of the pavement.

Data for this research was collected from two paving projects on three different bridges. The first bridge tested was an overpass over Route 6 located on Route 195 in Willimantic, CT. The bridge was milled and overlaid with a 12.5 mm, traffic level-2, Superpave mix. The second paving project contained two bridges on I-91 southbound between Wethersfield, CT, and Rocky Hill, CT. The first bridge (ID# 01457) tested was an overpass over Elm Street, in Wethersfield. The second bridge tested (ID# 01454) on this project was a large bridge over Middletown Avenue and a set of railroad tracks, also in Wethersfield. Both of these bridges were overlaid with a 12.5 mm, traffic level-4, Superpave surface course.

At each location the non-destructive field measurements consisted of nuclear density measurements and a field permeability measurement. For nuclear density testing, the CAP Lab's nuclear density gage was placed on the exact location where the permeability test was to take place. A density reading was taken, then the gage was rotated 180 degrees and a second density reading was taken. Field permeability measurements were obtained using the Gilson AP-1B field permeameter, which was based on the National Center for Asphalt Technology (NCAT) field permeameter design. The falling head principal of the permeameter allowed for a calculation of the coefficient of permeability using Darcy's law. In the original proposal for this research, a core was to be cut from the exact location of the nuclear density readings for laboratory permeability testing. Coring on a bridge deck is a delicate task and damage to the underlying membrane on the bridge could result in premature environmental damage to the structure. Therefore, cores were not taken from the bridge deck for this research. The previous task in this research series (Part C) indicated measured field permeability is typically higher than lab permeability due to the lack of lateral confinement in the field test. Therefore, the permeabilities reported in Part D may have been higher (by a factor of 1.5 on average) than the measured lab permeability.

Part D. Conclusions and Recommendations

The objective of this study was to determine if non-destructive permeability testing could serve as a resolution tool for disputes of in-place pavement density for bridge decks. Based on the density and permeability data obtained for this research there was a strong relationship between density and permeability for the bridges tested. However, for a permeability to be used in dispute resolution the field testing method would need to be much more sophisticated than current methods. The issues mentioned within Part D indicated the appearance of seal leakage may prohibit this test from being accepted as a dispute resolution tool. Since an actual leakage would result in a high permeability measurement and projected low density, the appearance of a leak would open the door for disputes over the validity of individual tests. Furthermore, there was the very subjective nature of the test. The fall in head is recorded by eyeballing the water level and recording the time between observations. In a dispute resolution case, observations need to be objective, with the potential for human error minimized. A contractor could argue that the inspector misread the graduations on the permeameter or recorded the wrong time intervals. The permeameter has the potential to cause more disputes than it would resolve, and therefore, deemed unsuitable for use in dispute resolution of pavement mat or bridge deck density.

Part D. References

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Part E. Compare Field Performance of Superpave and Traditional Mixtures

Part E. Background and Summary

Superpave mix design methods were developed at the national level in a wide-scale effort to improve upon the quality, structural integrity and service life of hot-mix asphalt (HMA) roadways. Structural integrity was a primary focus during the development of the Superpave system as roadways constructed under traditional design methods frequently experienced permanent deformation that presented itself in the form of wheel path rutting. The Superpave mix design system promoted stone-on-stone contact to create a greater degree of internal friction within the pavement. This increased internal friction was intended to allow the denser and more angular stone matrix to absorb and distribute loading stress from traffic, while resisting rutting to a much more substantial degree than traditional mix designs. The PG asphalts used in Superpave were also developed to address temperature susceptibility (hot and cold) of in place asphalts, and to extend the range of temperatures that could be experienced by in-place pavements without detrimental results (i.e, less cracking induced by cold and stiffness, less rutting and shoving induced by heat and viscosity).

After development, the Superpave system was widely adopted by agencies all across the United States. Because the Superpave system wasn't developed until the 1990's, there were no available studies from which long-term performance of Superpave roadways could be examined, and there was no long-term research available comparing performance characteristics of traditionally designed pavements and pavements designed under the Superpave protocol.

At the time of this research, 2011 – 2013, some pavements in Connecticut designed under the Superpave system had been in service in excess of 10 years, and many of those surfaces had been overlaid. ConnDOT made the full switch from Marshall mixes to Superpave mixes in 2004. Concerns were expressed by ConnDOT regarding the durability of Superpave mixes, specifically with respect to excessive cracking. This research was intended to compare those pavements with similar pavements of the same age and traffic levels that were designed using the traditional Marshall method.

This research examined and compared performance characteristics of Superpave mixes and mixes designed using the Marshall method throughout the state of Connecticut. Three different data collection methods, including, Pavement Serviceability Ratings, photolog analysis and field evaluations of several roadways constructed in Connecticut, were used to provide insight as to how the two different pavement design types performed in the field, with respect to each other. This information provided long-term performance data comparing the two methods and was as a tool in future long-term performance comparisons, which were conducted.

Part E. Conclusions and Recommendations

In light of the three different methods used to compare the performance of Superpave pavements and Marshall pavements, the research team found no conclusive evidence of a difference in the pavements' ability to resist distress from either traffic loading or weather patterns. It should be noted that there were no instances of significant rutting or wheel path fatigue observed during any of the site visits or during the photolog analysis on the selected sections.

The results of all analysis and of all examinations of numerous photolog images and analysis from the field visits, did not indicate that there was any significant difference in performance between Marshall pavements and Superpave pavements placed in Connecticut from 2001 through 2003.

The reader should take into consideration that visual analysis of pavements involves a small amount of interpretation.   The images from the photolog and site visits were analyzed visually by the research team, and conclusions were taken from these analyses.

What also needs to be considered for any future evaluations are the changes that take place with the CTDOT specifications from the time of implementation of Superpave in 2004 through current practice. It is more difficult to evaluate performance of pavement types amidst ongoing specification changes. There are some specification changes that have taken place since the period covered by this report ended, such as increases in the amount of allowable RAP content, the elimination of Superpave traffic level 4, minimum asphalt content specifications, maximum voids in the mineral aggregate specifications and changes in the specified low temperature performance grade of the liquid asphalt. As material and construction specifications change over time, noticeable performance deficiencies from past paving projects have the tendency to have already been addressed.

Part F. Modify ConnDOT Databases to Process HMA Test Data for Statistical Validation

During the course of the research that took place under SPR-2250, this task was removed from the work plan with mutual agreement between ConnDOT and UCONN.

Part G. Prepare Final Report, Executive Summary and Presentation

This document serves as the Final report for SPR-2250. The Executive Summary for SPR-2250 can be found after Page vi of this document.

Appendix A – List of Previously Published Reports for Topics A Through E of this SPR-2250 Research Project

Part A – Report Number CT-2250-1-08-11. "*Hot Mix Asphalt Research Investigation for Connecticut: Part A – Reduction in the Number of Superpave Mix Design Levels*"

Part B - CT-2286-F-18-5. "*ConnDOT Specification Requirements for Minimum Asphalt Requirements"*

Part C - CT-2250-2-10-9. "*Hot Mix Asphalt Research Investigation for Connecticut: Part C – Permeability/Porosity Testing of HMA Mix Designs*"

Part D - CT-2250-4-13-3. "*Hot Mix Asphalt Research Investigation for Connecticut: Part D – Evaluate the Feasibility of Using Permeability for In-Place Density Dispute Resolution on Bridge Decks*"

Part E - CT-2250-3-12-9. "Comparison of Field Performance of Superpave and Traditional Marshall Mixes"