Hot Mix Asphalt Research Investigation for Connecticut, Part D- Evaluate the Feasibility of Using Permeability for In-place Density Dispute Resolution on Bridge Decks

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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**

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. The relationship between density and permeability indicates 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 the CT HMA study is to determine if measuring the permeability of a pavement on a bridge deck will work as a non-destructive dispute resolution test for the in-place density of the pavement. The data collected and analyzed for this research indicates there is an exponential growth in permeability as the percent air voids increase. However, for a permeability based dispute resolution process to be implemented the field testing method would need to be much more sophisticated than current methods. The subjective nature of the test has the potential to cause more disputes than it would resolve.

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Introduction

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. Bridge deck pavements typically have lower densities due to the contractor's inability to use a vibratory compactor on the bridge. Vibratory compactors are generally not used on bridges due to fears of dynamic loading stresses and damage to the structure. The relationship between density and permeability indicates 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 the CT HMA study is to determine if measuring the permeability of a pavement on a bridge deck will work as a non-destructive dispute resolution test method for the in-place density of the pavement.

Background

Permeability in asphalt pavements is related to aggregate size, shape and gradation, but most importantly air void content (Maupin, 2000). Previous research efforts have investigated the relationship between aggregate, compaction and permeability. This section will review the current research on the parameters that impact permeability and the methods used to collect permeability data.

Permeability refers to the unidirectional rate at which water flows through a specimen. *Porosity* is defined as the percentage of air voids in the compacted HMA sample that are accessible to water. The term *porosity* is the ability to absorb fluid while the term *permeability* is the ability to transmit fluid. Note that there is a big difference between permeability and porosity. A substance may be quite porous, but unless the voids are connected so that a liquid can flow through the material it is not permeable. Past research suggests porosity may be a better measure of a pavement's resistance to air and water infiltration when compared to permeability (Mogawer et al., 2002). However, a specimen can be porous but not permeable, but it cannot be permeable unless it has porosity. Therefore, measuring only porosity may not be a great indicator of potential for water and air infiltration. Permeability is the focus of this research, as well as the majority of previous research.

Field Permeability Testing

Field testing for permeability involves the use of a falling head permeameter. The field permeameter is sealed to the pavement being tested using a putty or wax. Once sealed the permeameter is then filled with water. The permeameter consists of 4-cylinders of various sizes that decrease in diameter in stages as the water level increases (Figure 1). Graduated markings on the side of the permeameter allow the user to record head readings at timed intervals. As a result, pavement permeability can be estimated based on the change in water height over time. Field permeability testing on pavement is not unidirectional, in other words, the movement of water is not confined to just passing perpendicularly through the pavement. The equations used to compute the field permeability assume unidirectional flow. Therefore, it would be expected that field permeabilities would be higher than laboratory permeabilities if all other things are constant. Even though the computation of field permeability is flawed, it is still a relative measure to establish how easily water and air can move through the pavement.

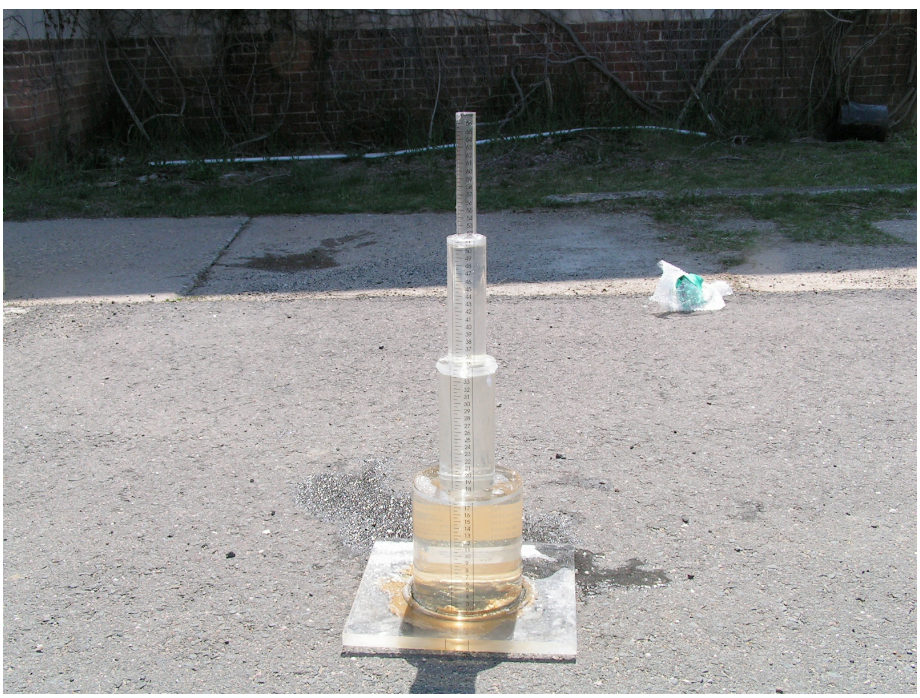

Figure 1: Field Permeameter

Factors that Impact Permeability

An underlying factor that contributes to permeability and porosity is the amount of air voids contained in the specimen. In asphalt pavements air void content is reduced using compaction to increase the density of the pavement. Therefore, the degree of compaction (density) should be related to the permeability of the pavement. Early work on permeability indicated a pavement with air voids greater than 8 percent was susceptible to excessive permeability (Zube, 1962). This threshold of 8 percent was also confirmed by Brown et al. (1998) almost three decades later. However, the development and implementation of Superpave mixes warrants a second look at the permeability density relationship. Connecticut's first large-scale SUPERPAVE project was placed on State Route 2 in the towns of Colchester, Bozrah and Lebanon, between May and September 1997 (FHWA, 2008). Investigations into Superpave permeability indicate fine-graded mixes are relatively impermeable even at air voids significantly higher than 7 percent (Choubane et al. 1998). The fine particles in these mixes reduce the interconnectivity of air voids, thus limiting permeability. Kanitpong et al 2005 researched permeability in fine graded mixes and recommends the minimum density should be set at 93.8% (6.2 % air voids) to control permeability in fine graded Superpave mixes.

Previous research indicates mix design and aggregate size play a role in permeability of pavements (Cooley and Brown, 2000; Maupin, 2000; Mallick et al. 2003). Since aggregate type, mix design and density are directly related to permeability this research is aimed at identifying if surface course pavements used on bridge decks are statistically different from mat course permeability.

Data Collection

Data for this research was collected from two paving projects on three different bridges. The first bridge tested is 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 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.

Field Testing

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 is 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 as presented in Equation 1. In the original proposal, 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) indicates measured field permeability is typically higher than lab permeability due to the lack of lateral confinement in the field test. Therefore, the permeability's reported here may be higher (by a factor of 1.5 on average) than the measured lab permeability.

$$k = (aL/At)\ln(h2/h1) \qquad \text{Equation 1}$$

where:

k = coefficient of permeability
a = cross sectional area of the standpipe
L= thickness of the test specimen
A = cross sectional area of the test specimen
t = time between h1 and h2
h1 = head at end of test
h2 = head at start of test

Field Permeability Testing Observations

Conducting the field permeability tests presented a few challenges that were overcome, but should be noted for future testing. As noted in the Part C permeability report, the main issue that arose with the field permeameter was the ability to make and maintain a good water-tight seal with the pavement. For this data collection wax toilet bowl flanges were used to seal the permeameter to the pavement. These wax flanges provided a very tight seal to the pavement and filled in any surface voids that may allow water to escape between the permeameter and pavement surface. One advantage of the wax flange is that the pavement need not be warm to get a good seal like when using the plumber's putty. The wax flange created a seal that was so tight it became very difficult to remove the permeameter from the pavement. In fact a crowbar was needed to pry the permeameter free. Similar to the Part C permeability report, the investigator noted what appeared to be leakage from the seal under the permeameter. However, due to the strength, contiguity and hydrophobic nature of the seal witnessed during testing, the investigator is confident that the seal did not fail. The apparent leakage was hypothesized to be water traveling laterally through the top layer of voids in the pavement and then resurfacing up and out of the pavement once past the seal. However, even the appearance of seal leakage could prohibit this test from being accepted as a dispute resolution tool

Results

The field permeability data and the density data were used to generate a plot of coefficient of permeability by percent air voids (Figure 2). Similar to the results for the mat data collection in Part C, there is an exponential increase in permeability as the percentage of air voids increases. Figure 3 contains permeability density plots of 12.5 mm Superpave mixes obtained in Part C of the CT HMA research plan. The plots below indicate that bridge deck permeability follows a similar trend to the one seen in the mat data. However, the exponential rise in permeability is not as severe in the bridge deck data. These data also indicate that at a lower percentage of air voids the bridge deck surface course is slightly more permeable than a mat course. This is most likely due to the fact that on bridge decks the contractor is not allowed to use the vibratory roller to compact the pavement. Therefore, even at the same or similar density the bridge deck may have more interconnected air voids, and thus be more permeable, due to the lack of vibration in the compaction process.

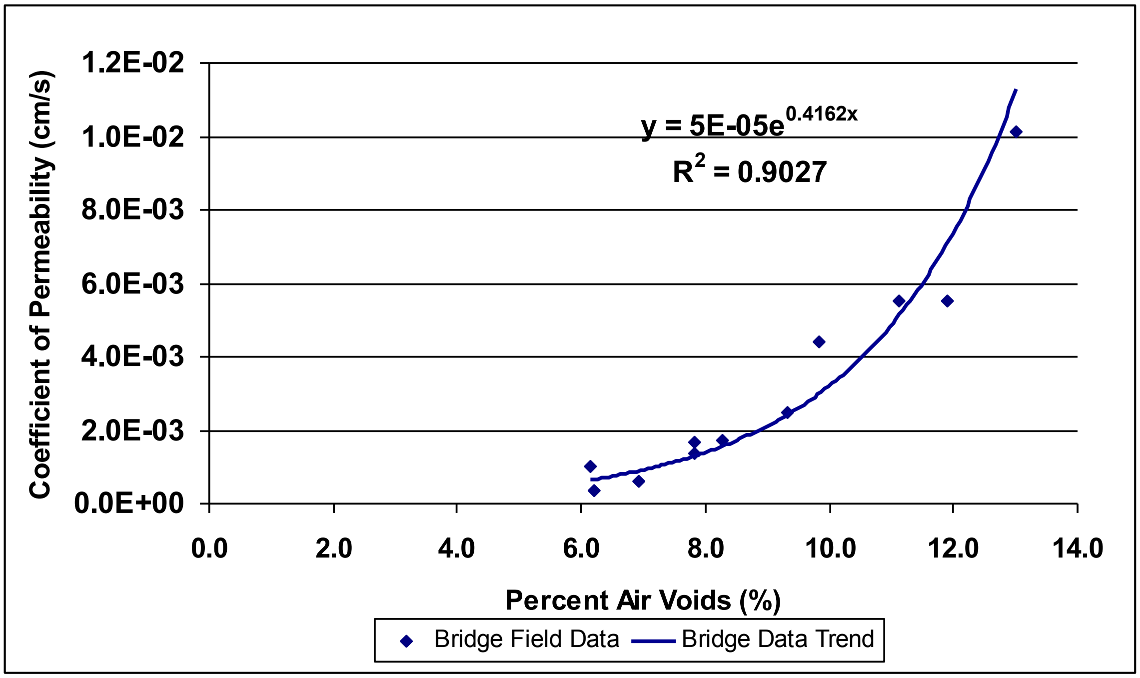

Figure 2: Bridge Deck Permeability-Density Plot

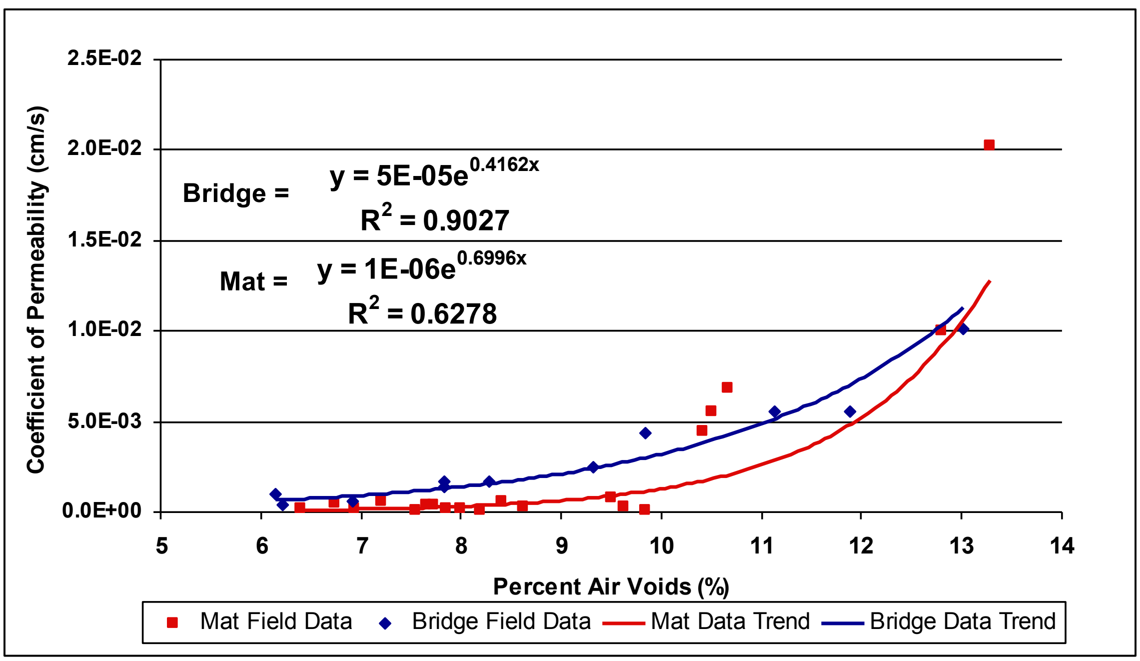

Figure 3: Mat Vs. Bridge Deck Permeability-Density Plots

Conclusions

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 is 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 in Part C of this research project and within this current report, 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 is 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 is therefore deemed unsuitable for use in dispute resolution of pavement mat or bridge deck density.

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