State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2002

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Lab & Field Evaluation of Superpave Mixes Designed with Different PG Grades and Aggregate Angularities	**Project ID:** 0092-45-98
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Error! Bookmark not defined.	**Approved Starting Date:** Dec 6, 1999
Approved by COR/Steering Committee: $80,001.00	**Approved Ending Date:** Jun 30, 2002
Project Investigator (agency & contact): Hussain Bahia: UW-Madison	

Description: In recent years, a significant tonnage of asphaltic concrete materials have been designed and constructed in Wisconsin following Superpave mix design protocol. In the year 2000, the Wisconsin Department of Transportation (WisDOT) is shifting from Marshall design to Superpave design for all asphaltic concrete pavements. Section 407 of the WisDOT Standard Specifications has recently been modified to incorporate modified gyrations and air voids requirements for five separate asphaltic concrete mixture types. These revisions will take effect in the year 2000 for all SHV mix types and in the year 2001 for SMV and SLV mix types.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
$80,001.00	**$26,667.00**	**$0.00**	**$0.00**

Progress This Quarter:

(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

The final draft report revisions were almost completed and a meeting with the flexible technical oversight committee (TOC) was completed during this quarter. A new design criterion was discussed and reviewed during the meeting.

The main findings of the study include the following:

1. Using FAA to control required angularity can result in inferior mixtures
2. There are significant interactive effects between angularity, garadtion, and asphalt content
3. Asphalt grade and content could have significant effects on peraforamnce of mixtures.
4. The allowable varation of +/- 0.5 asphalt content would allow significant and unaccepatbel varaitaion in performance.
5. A more direct measure of mixture stability and resistance to compaction is rewuired to replace the limits on FAA values and allowable asphalt grade and content varaiation.

Work Next Quarter:

The final report submittal will be completed during the next quarter, specifically during late July.

Circumstances affecting progress/budget:

No circumstances affecting progress / budget

Gantt Chart:
Attached Excel File (Q2 2002.xls)

Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2002

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Guidelines for Selection of PG Binders for Asphalt Mixes	**Project ID:** 0092-01-01
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Tom Amon	**Approved Starting Date:** Nov 15, 2000
Approved by COR/Steering Committee: $99,829.00	**Approved Ending Date:** May 15, 2003
Project Investigator (agency & contact): Hussain Bahia: UW-Madison	

Description: In January 1997, the Wisconsin Department of Transportation made the switch to use Performance graded (PG) binders in place of the penetration and viscosity graded asphalts that had been historically used. The decision at that time to specify PG58-28 as the standard grade for use was based on this materials similarity to the asphalts that we had previously used, the wide availability of the material in our region, and the fact that there was little or no difference in cost. This material has worked well for us, but we are starting to become aware of situations and locations where use of some of the other grades may be of benefit. We have placed limited amounts of other PG graded material in the state, but no coordinated effort has been made to track these projects. In order to determine guidelines for the selection of PG graded binders for use in Wisconsin, AASHTO MP1 should be implemented based on climatic data, pavement temperatures, application, material availability, risk to the Department, and economic factors.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
$99,829.00	**$33,276.33**	**$0.00**	**$0.00**

Progress This Quarter:
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

During the past quarter laboratory testing and analysis of results based on the NCHRP 9-10 protocols for several of the asphalt binders selected for the project continued. The results were used to develop a tentative proposal for selecting binders for different application conditions based on rutting behavior of binders. The proposal for selection of binders based on fatigue behavior has also been started but will require further testing. The specifc results and data analysis during last quraeter are described in the following sections:

- **LAST Test Results**

Table 1 is an example of the results from running DSR tests on samples taken after four periods of storage for the binder C5. In this test the binder is stored at 165 C in container uniformly heated such that there is no agitation (static storage) for 48 hours. During the storage the binder is sampled from top and bottom of the storage container and tested with the DSR at 5 .o and 50.0 rad /s at the high-grade temperature (HT) and the intermediate grade temperature (IT). The ratio of top G* value and phase angle value (delta) of the top sample to the bottom sample is calculated (Rs). If the ratio is in the range of 0.8 to 1.2, it is assumed that there is no separation and the the binder is considered stable. As can be seen, in the case of this binder, there is no critical potential of storage instability during storage at elevated temperatures without mechanical agitation. The same analysis is done for the binder while it is being agitated using a mechnical mixer. For this binder, the results with agitation have shown that this binder to be less stable during storage with agitation as shown by the results at the 6-hour sampling. Storage stability of other binders tested varied depending on agiataion and source or type of modifier. For example binder (B3), which was proved to be containing particular additives from the PAT tests, was less stabile than theother binders. The DSR tests reveal that binder B3 have a problem of segregation at 6 and 24 hours sampling under the high agitation storage conditions.

The results collected so far indicate that a number of the binders show a potential for instability and thus need to be monitored during storage in the field. More binders are planned to be tested in order to measure their potential for storage instability in the near future for this project.

Table 1 The Result of the LAST Tests for C5 Binder

Conditioning Step	External Heat without Agitation							
Frequency (rad/s)	5.0		50.0		5.0		50.0	
Temperature ©	HT		HT		IT		IT	
Time of Sampling (hr)	G*	Delta	G*	Delta	G*	delta	G*	delta
0 (top)	1,200	86.3	10,500	82.1	1,240,000	58.3	12,500,000	35.5

Gantt Chart:
Attached Excel File (Q2 2002.xls)

Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation
RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2002

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Gyratory Compactor to Measure Mechanical Stability of Asphalt Mixes	**Project ID:** 0092-01-02
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Error! Bookmark not defined.	**Approved Starting Date:** Nov 1, 2000
Approved by COR/Steering Committee: $55,337.00	**Approved Ending Date:** Nov 1, 2002
Project Investigator (agency & contact): Hussain Bahia: UW-Madison	

Description: The Superpave volumetric mixture design procedure does not include a measure of mechanical stability of asphalt mixtures. Although there are few efforts at the national level to develop a separate test for measuring a performance property, it is not known whether these efforts will be successful. It is also not know whether such test will be practical enough to be used as a quality control test by the contractors in the field.

Recent research work at the University of Wisconsin-Madison (funded by FHWA in 1998-99) has resulted in developing a simple accessory that can be used to measure internal friction of asphalt mixtures during the compaction process. The simple device has been used to test several mixtures produced in the field by contractors in Wisconsin. The results are very encouraging and show a high potential for success. This research effort has also indicated that the Superpave Gyratory Compactor could be modified to provide the means for measuring the mechanical stiffness and strength at conditions that simulate field conditions under traffic.

There is a need to continue this effort and explore all possible uses of the gyratory compactor to measure frictional resistance of mixtures during compaction and also mechanical stability under traffic conditions. The Wisconsin DOT and the Industry in Wisconsin can benefit of a simple device that is part of the gyratory compactor that can measure performance-related properties of mixtures. Such a device could be used to enhance the mixture design process to include a mechanical stability measure.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
$55,337.00	**$18,445.66**	**$0.00**	**$0.00**

Progress This Quarter:
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)
Additional compactions were conducted to adjust the mixes that didn't pass the volumetrics design criteria (%Gmm @ Nini, Ndes, and Nmax). All twenty four (24) asphalt mixtures passed the volumetrics design criteria and the collection of performance data has continued last quareter. The following sections describe the progress achieved.

Establish a Mixture Design Criterion

Assembling of a database is part of Task 3 of the project (Establis h a Mixture Design Criterion). This work has been continuing as the data were been collected. The database is used to establish the mixture design criterion that is suitable for Wisconsin and that is compatible with the Superpave mixture design procedure as much as possible. This database, which is the accumulation of the past two years laboratory work at the University of Wisconsin-Madison, includes 70 diferent mix designs. All 70 mix designs are from asphalt contractors in the state of Wisconsin and all have passed SUPERPAVE and WisDOT requirements when designed. The mix designs were divided into 29 E-3 mix designs, 32 E-10 mix designs, and 9 E-30 mix designs. In the following sections, the acceptance criteria for the construction and traffic indices are discussed and derived.

Mixture Resistance to Compaction

To minimize the possibility of harsh (difficult to compact) mixtures a maximum limit of the resistance of a mixture to compaction should be used. In this study, the resistance to compaction to 92 % Gmm was measured using the construction indices (CEI and CFI). CEI is dervived from the Gyartary Compactor without any mdofiaction, while CFI is measured in the Gyratory Compactor by using the GLPA, which is a specially designed accessory. The averages of CEI and CFI with minimum and maximum ranges (shown as bars) are shown in Figures 1, 2 calssifed based on traffic class of mixtures.

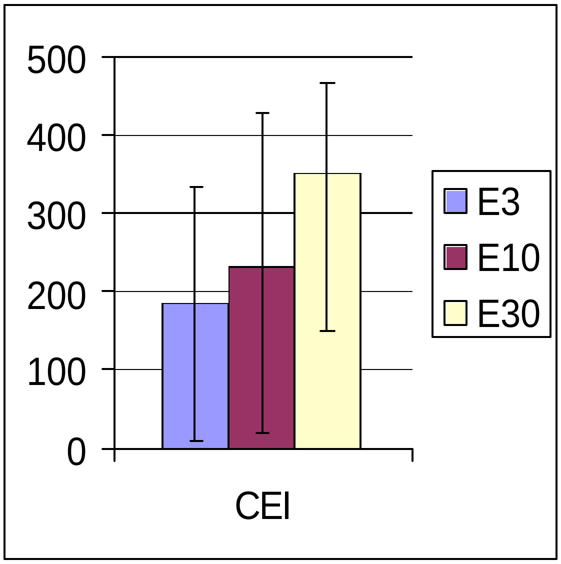


Figure 1: CEI Averages

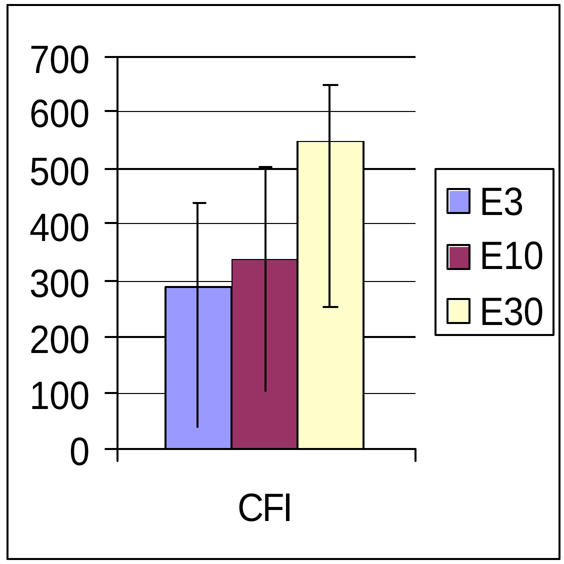


Figure 2: CFI Averages

These charts clearly show that the higher the mixture grade, in terms of ESAL count, the more difficult it is to compact, as shown by higher CEI and CFI values. This is not a surprise and it is reasonable to assume that mixtures designed for higher ESAL level are more resistance to compaction.

To derive an acceptance criteria it is reasonable to assume that, since these mixtures have been used in the field, the average value of CEI and CFI is a good starting criteria for mixture design. Also since CEI and CFI are highly correlated, and since CEI does not require any additional equipment nor a GLPA, it is reasonable to recommend that the criterion be based on CEI, which is measured from the densification curve currently measured by all types of gyrator compactors.

There are two options to implement the compaction criterion. One maximum limit could be used regardless of the ESAL grade of the mixture. This could be justified if we can assume that the performance under traffic conditions is independent of the performance of the mixture during compaction. Using the same logic, it can be said that the % Gmm at Ninitial is independent of the % Gmm at N max, which is true for many mixtures. If we accept this logic, we can select a single limit for CEI of 250 and also a single limit of 350 for CFI. No mixture should be accepted if CEI exceeds 250 and/or CFI exceeds 350 because it will require excessive compaction effort to construct the asphalt pavement. This limit, although not validated, is deemed reasonable since there is more than half of the mixtures, within each mixture EASL grade could meet this limit but it will not allow mix designs that require an excessive amount of compaction work. The distribution for the construction indices (histogram) is shown in Figures 3, 4.

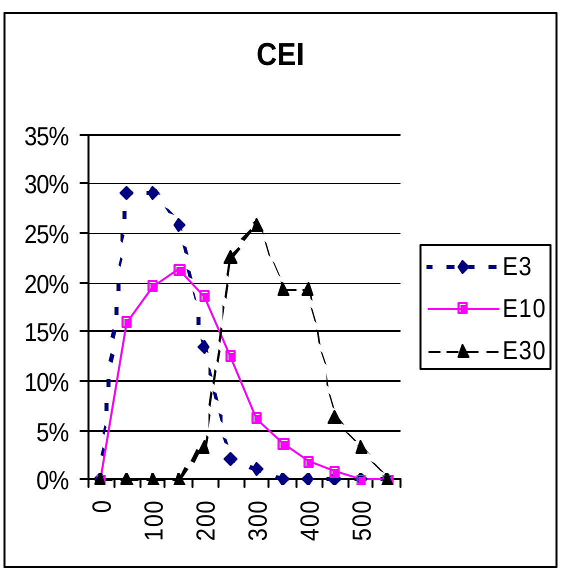


Figure 3: CEI Histogram

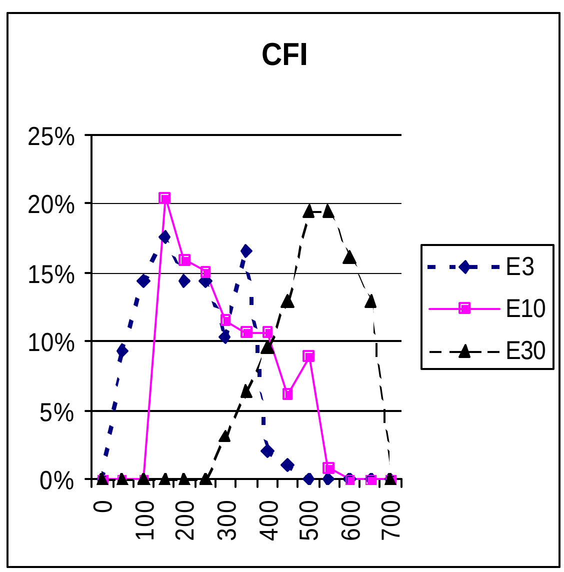


Figure 4: CFI Histogram

The other option for establishing criteria is to select an increasing scale related to the EASL grade of the mixtures. Using the data shown in Figure 3 and 4 we can select the following scaled limits (Table 1):

Table 1: Construction Indices Maximum Values

Mixture Type	***CEI maximum value***	***CFI maximum value***
E3	100	200
E10	200	350
E30	300	500

The best approach at this time is to validate the criterion in the field before a decision could be made on using the single limit or the increasing scale shown in the table above.

Mixture Resistance to Densification and Distortion Under Traffic

For performance under traffic, the traffic energy and force indices (TEI, and TFI) could be used to derive a criterion to ensure mechanical stability. The TEI is calculated directly from the desnifiaction curve measured by the Gyratory Comapctor without any mdofictaion while the TFI requires using the GLPA in the gyratory comactor. The averages of the TEI and trheg TFI with minimum to maximum range bars are shown in Figures 5 and 6 for all mixtures tested in the gyratory compactor.

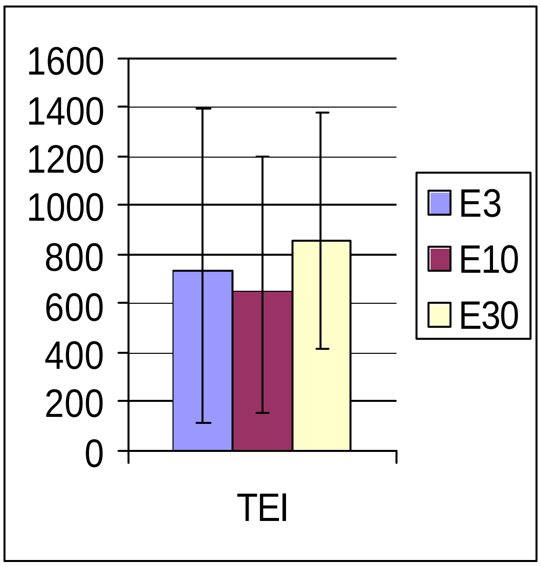


Figure 5: TEI Averages

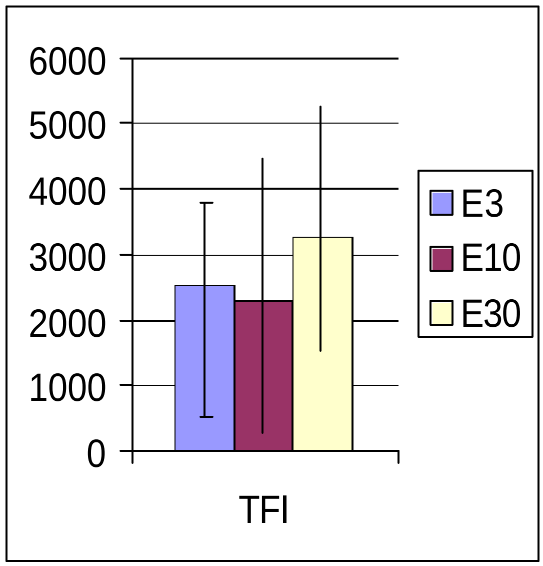


Figure 6: TFI Averages

Unlike the CEI and the CFI plots, it can be seen that there is no good trend separating the mixtures based on the ESAL grade. It is observed that the average values of the TEI for the E 3 mixtures is in fact higher than the average for the E10 mixtures and within 15 % of the E30 mixtures. It is also seen that the range in the values for the three mixture grades overlap significantly. This could be possibly explained vy the fact that the current Superpave mixture design focus on volumetrics at selected points (Ndesign and Nmax) and requires a one sided limit on % Gmm at Nmax. In other words, it does not consider the benefit of a mix that would maintain the % Gmm as cloase as possible to the required % Gmm of 96% at Ndesign. It also scales back the number of gyrations with the ESAL grade which results in more confounding effects.

From the results shown in Figures 7 and 8, an approach similar to the one used to derive the limits for CEI and CFI could be used to derive the criterion for the TEI and TFI. Using the single limit approach, the minimum limit for TEI of 750 and a minimum limit of 2500 for TFI could be proposed to limit the possible distortion and densification that would lead to rutting under traffic. This is based on the assumption that if more work is measured by the gyratory to densify the mixture from 92 % Gmm to 98 % Gmm, then this mixt ure is less prone to rutting under traffic. These limits were selected because it appears that more than half of the mixtures which are used today could pass these limits. This will naturally need verification in the field.

To use the increasing scale criteria the distribution for the traffic indices (histogram) will need to be evaluated. The frequency distribution of TEI and TFI for the three mixture grades are shown in Figure 7 and 8, respectively. It appears that the TEI results for the E 3.0 and E10 mixtures overlap significantly while those for the E30 are much higher. Since it is logical to assume that the E3.0 mixtures require lower values of TEI and TFI than the E10, it is proposed that the following table 2 be used as a starting point for validation and future implementations.

Table 2: Traffic Indices Minimum Values

Mixture Type	*TEI minimum value*	*TFI minimum value*
E3	400	2000
E10	800	3000
E30	1200	4000

The values are based on the general concept that the mixtures tested in this study are all successful mixtures that would perform well. By taking the limits at about 50 percentile we are targeting the average successful mixture. One could argue that taking the 70 percentile is a better target, the problem is that we have no idea how these limits would correlate to actual performance in the field.

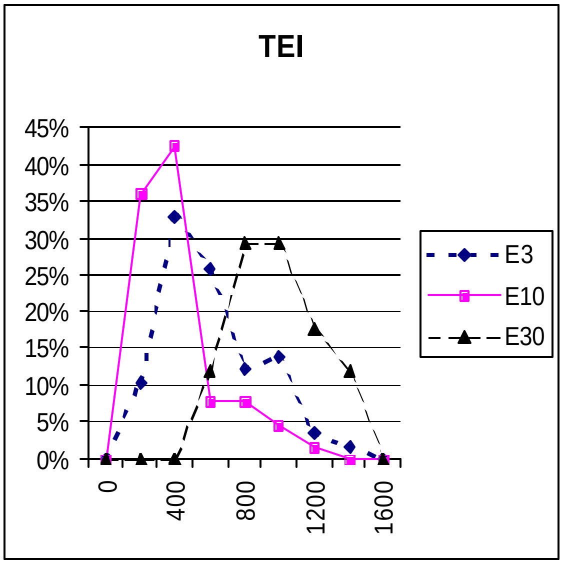


Figure 7: TEI Histogram

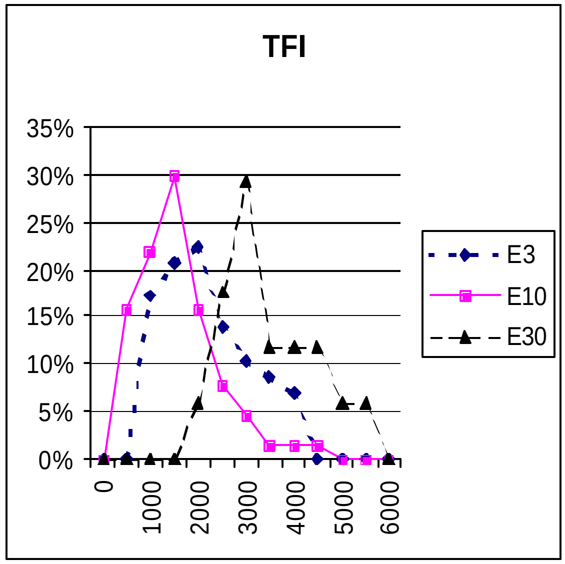


Figure 8: TFI Histogram

Correlation between Gyratory Loadcell Plate Assembly and the NCHRP 9-19 (Arizona State University)

A correlation between these two techniques is currently being created by compacting laboratory samples using the gyratory loadcell plate assembly (GLPA) and then being cored and run using the NCHRP 9-19 procedure since the NCHRP 9-19 procedure has been proven to correlate with permanent deformation in the field. Therefore hopefully the GLPA and the NCHRP 9-19 procedure will show a correlation therefore indirectly the GLPA will correlate with permanent deformation in the field.

Work Next Quarter:

A statistical analysis will be done to see the significant effects, and interactions of the 24 contractor mixes will be completed. Other tasks that will be continued next quarter will include the mixtuer simple performanmce test (NCHRP 9-19 proceduer) and the development of design criteria and the field study.

Circumstances affecting progress/budget:

The coring rig used to core 4" samples from the laboratory compacted samples was broken most of the second quarter of 2002, therefore only a few samples were cored during the past quarter.

Gantt Chart:

PROJECT I.D.	STARTING DATE	COMPLETION DATE	MONTH	REPORT #
PROJECT # WISDOT	**NOV 1, 2000**	**Nov 1, 2002**	**June 2002**	7

CONSULTANT FIRM NAME	% TIME ELAPSED	TOTAL PROJECT FUNDING	CONTRACT FUNDING
UNIVERSITY OF WISCONSIN - MADISON	80.00%	100%	100%

NAME OF STUDY

Using the Gyratory Compactor to Measure Mechanical Stability of Asphalt Mixtures

TASK *	YEAR / MONTH	2000 N	D	2001 J	F	M	A	M	J	J	A	S	O	N	D	2002 J	F	M	A	PERCENT OF Project	Task Completed Last Report	Task Completed This Report	Project Completed
TASK 1 : LITERATURE REVIEW																							
1.1 : Literature Review																				21	100	0	21.00
1.2 : Review Meeting																				4	100	0	4
TASK 2 : LABORATORY STUDY																				37.5	90	5	35.625
TASK 3 : ESTABLISH MIXTURE DESIGN CRITERIA																				17	25	30	9.35
TASK 4 : PLANS FOR FIELD STUDY																				8	30	20	4
TASK 5: FINAL REPORT																				12.5	0	0	0
SHOW PROGRESS BY USE OF A BAR CHART:	SCHEDULED																						
	COMPLETED																			100			73.98

(Submitted by)

(Date)

Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2002

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: HMA Moisture Damage as it Relates to Pavement Performance	**Project ID:** 0092-01-03
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Error! Bookmark not defined.	**Approved Starting Date:** Nov 15, 2000
Approved by COR/Steering Committee: $50,753.00	**Approved Ending Date:** May 15, 2002
Project Investigator (agency & contact): Hussain Bahia: UW-Madison	

Description: The Wisconsin Department of Transportation (WisDOT), in the early 1990s, began to look at requiring the use of a test in trying to predict the potential susceptibility of any given mixture to moisture damage and its' associated pavement distress(es). At that time, the Tensile Strength Ratio (TSR) test chosen was ASTM D-4867. The specification also required that when the TSR value of a mixture, at optimum %AC, fell below 70%, then the contractor was required to add an anti-strip agent to the mixture. Additionally, if an anti-strip agent was used, the new TSR value now had to meet or exceed a higher parameter of 75%. Since the implementation of this requirement a question has been raised as to whether the addition of the anti-strip agents, and additional costs incurred to all projects in trying to predict the potential susceptibility, has actually helped solve a problem that might not have even existed or has been accounted for by ensuing mixture and aggregate requirements. It was felt that a study was needed to further investigate the extent and possible causes of AC pavement moisture damage and to determine the severity of the problem.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
$50,753.00	**$25,376.50**	**$0.00**	**$0.00**

Progress This Quarter:
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

- The final report is being reviewed and edited by the project investigator, and then it will be sent to the TOC committee for review and correction within the end of August.
- The project team requests a no cost extension of this project. The extension of the project is for the review and comment by the committee.
- The project team has developed an adhesion test and a cxohesion test that could be used to replace the current TSR testing.
- The project team is also experiementing with a simple wash test used by the Canadian road authority in Wuebec as an alternative for moisture damage testing.
- The interim findings of the research confirm that using anti-strip additives improve adhesion of binders to certain aggregates very significantly while do not affect others.

Work Next Quarter:

- Inclued some of the findings regrdaing the adhesion test and the cohesion test in the final report
- Inclued the finding about the wash test in the analysis
- Submit the final report to the TOC committee for review.
- Complete the final report.

Circumstances affecting progress/budget:

Gantt Chart:

PROJECT I.D.	STARTING DATE	COMPLETION DATE	MONTH	REPORT #
PROJECT # WISDOT	**NOV 01, 2000**	**APRIL 30, 2002**	**J U N 0 2**	7

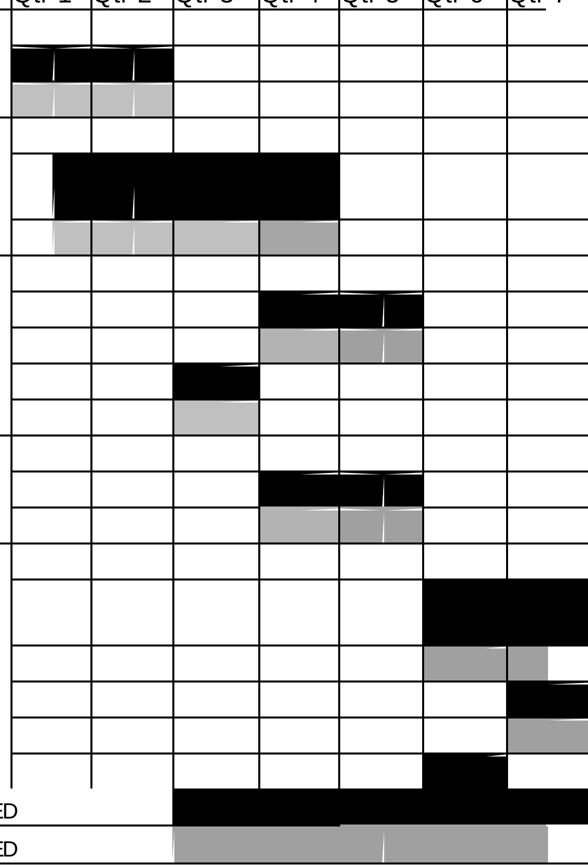
CONSULTANT FIRM NAME	% TIME ELAPSED	TOTAL PROJECT FUNDING	CONTRACT FUNDING
UNIVERSITY OF WISCONSIN - MADISON	29.00%		10 0 %

NAME OF STUDY

EVALUATION OF THE EXTENT OF HMA MOISTURE DAMAGE IN WISCONSIN AS IT RELATES TO PAVEMENT PERFORMANCE

YEAR: 2000 (Qtr 1); 2001 (Qtr 2 – Qtr 5); 2002 (Qtr 6 – Qtr 7)

MONTH: Qtr 1, Qtr 2, Qtr 3, Qtr 4, Qtr 5, Qtr 6, Qtr 7



PERCENT OF

TASK *	Project	Task Complete	Task Complete	Project
TASK 1 : Collect data and Conduct Data Analysis	20	0	100	20
TASK 2 : Assessment of the Moisture Damage Problem	34	0	100	34
TASK 3 :				
3.1 : Use and Cost of Additives	15	0	100	15
3.2 : Interim Report Meeting	2	0	100	2
TASK 4 : Expansion of Previous Study Implementation Plan	15	0	100	15
TASK 5 :				
4.1 : Final Report and Recommendations	10	0	70	7
4.3 : Meeting with the TOC	2	0	100	2
4.4 : Final Report Submittal	2	0	0	0
SHOW PROGRESS BY USE OF A BAR CHART: SCHEDULED / COMPLETED	100			95

Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2002

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Effect of Pavement Thickness on Superpave Mix Permeability and Density	**Project ID:** 0092-02-14c
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Error! Bookmark not defined.	**Approved Starting Date:** Nov 7, 2001
Approved by COR/Steering Committee: $225,321.00	**Approved Ending Date:** Nov 7, 2004
Project Investigator (agency & contact): Jeff Russell: UW-Madison	

Description: It is well recognized that density that could be achieved in the field is significantly affected by the maximum aggregate size of aggregates, the gradation, and the lift thickness. It is also well known that permeability of asphalt mixtures is a function of aggregate gradation, density achieved, and distribution of air voids. With the shift in mixture designs to Superpave methods, gradations on the coarse side of the maximum density line are being widely recommended and used. These gradations are unique in their densification characteristics and are claimed to be more permeable. It is not clear whether this trend is due to changes in the air voids distribution, the lower densities being achieved, or both. This trend is of special importance to Wisconsin as the shift to Superpave mixtures is underway.

Wisconsin has traditionally used 75-mm dense graded HMA overlays placed in two lifts, a 44-mm binder lift and a 31-mm surface lift. These lift thicknesses are based on the traditional rule that lift thickness be twice the maximum aggregate size. Starting in the year 2000, Wisconsin has decided to move from Marshall design to Superpave mixture design.
Superpave mixes tend to be harder to compact. Additionally, Superpave guidelines recommend the lift thickness be a minimum of 3 times the nominal maximum aggregate size. This poses two problems for Wisconsin:

1. The first is that the current design criteria for overlay thickness will result in thin-lifts of Superpave mixes that the AASHTO Lead States Committee has reported as having problems with pavement permeability and achieving pavement density.
2. The second is that these mixes may be impossible to compact in the field contributing to the permeability problem, even though they meet laboratory density criteria.

There is a need, therefore, for a study to evaluate the potential problems and to establish procedures to relate laboratory density to field study and to estimate or measure permeability during mixture design. The study also needs to define the relationship between lift thickness and aggregate gradations that will minimize the densification problem and address the permeability concerns.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
$225,321.00	**$56,330.25**	**$0.00**	**$0.00**

Progress This Quarter:
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

1. **Define Project to meet the Experimental Matrix**
   Table 1 shows the 8-project matrix which allows all combinations of the 3 variables to be tested, including 2-factor and 3-factor interactions. However, in an effort to minimize resources during the first summer of this project, the 4-project matrix is preferred (Table 2). At a minimum, the project team recommends to complete the 12.5-mm (surface lift) testing on Wis Ave and STH 23, and identify 2 future projects having these combinations:
   Project A: Gravel, Strong base, Coarse gradation
   Project B: Limestone, Weak base, Coarse gradation

Table 1 8-Project Matrix (2^3 design)

Source	Base	Gradation	Project
Limestone	Strong	Fine	Wisconsin Ave.
Gravel	Strong	Fine	
Limestone	Weak	Fine	
Gravel	Weak	Fine	STH 23
Limestone	Strong	Coarse	I-43

Gravel	Strong	Coarse	
Limestone	Weak	Coarse	
Gravel	Weak	Coarse	

Table 2 4-Project Matrix

Source	Base	Gradation	Project
Limestone	Strong	Fine	Wisconsin Ave.
Gravel	Strong	Coarse	
Limestone	Weak	Coarse	
Gravel	Weak	Fine	STH 23

2. Field Study Results

The projects that were completed for the field study during the last quarter are the followings:

2.1 <u>I-43 (Binder Layer)</u>

- The field density and field permeability data (using NCAT device from P&D) are shown in Table 1.
- The cored samples were taken and the lab density of the cores was measured by using CoreLok device. The results and the difference between lab and field density of the cores are also summarized in Table 1. Figure 1 shows the relationship between lab and field density. From this figure, it is observed that location (site) 1, 2 and 3 which are thicker lift have larger difference between lab and field density when comparing to location (site) 4, 5 and 6 which are thinner lift.
- Project team will cut the cored sample from site 1,2 and 3 to approximately 7 cm (to be closed to sample from site 4,5,6), and then measure the difference in density and permeability between upper and lower level of the cores.
- The relationship between the field permeability, density, and thickness of Project I-43 will be shown together with the laboratory results in the later part.

Table 3 Summary of Field Data for I-43 (Binder)

Site	Field Density	Lab Density	% Diff Density	Thickness (cm)	Field K (* 10^-5 cm/s)
1	93.12	94.81	1.78	14.605	14.80
2	91.25	92.94	1.82	13.335	220.00
3	90.74	92.72	2.14	9.525	170.00
4	93.21	93.67	0.49	6.985	198.00
5	92.26	93.19	1.00	6.985	266.00
6	92.87	93.50	0.67	6.35	387.00

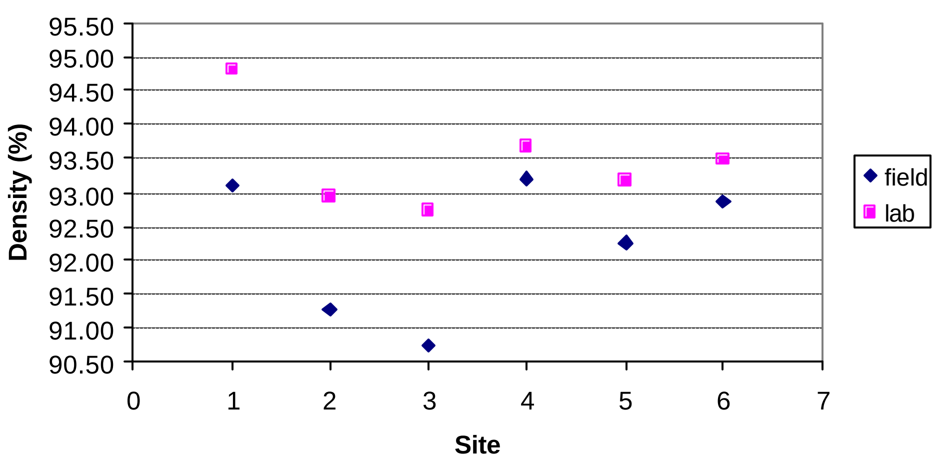


Figure 1 Relationship between field and lab density

2.2 STH-23 (Binder and Surface Layer)

- The field density and field permeability data (using NCAT device from Gilson Co.) of binder and surface layer are shown in Table 4 and 5.
- The relationships between field permeability, field density and thickness for both layers are shown in Figure 2-7.

Table 4 Summary of FieldData for STH-23 (Binder)

Site	BR (passes)	RR (passes)	FR (passes)	Field Density	Thickness (cm)	Field K (* 10^-5 cm/s)
1	2	4	1	91.10	7.9	46.51
2	2	3	2	91.38	8.075	37.79
5	2	4	2	90.63	4.225	75.19
6	2	3	3	92.00	5.225	64.87
7	2	7	3	90.22	3.375	87.46
8	2	1	2	90.20	3.125	149.63

Table 5 Summary of Field Data for STH-23 (Surface)

Site	BR (passes)	RR (passes)	FR (passes)	Field Density	Thickness (cm)	Field K (* 10^-5 cm/s)
1	4	12	2	93.77	3.5	13.39
2	1	3	1	93.42	4.3	34.69
5	2	14	2	93.20	5.5	17.04
6	2	15	2	93.24	5.85	74.52
7	2	8	2	92.26	6.05	81.06
8	2	7	2	91.54	6.45	177.4

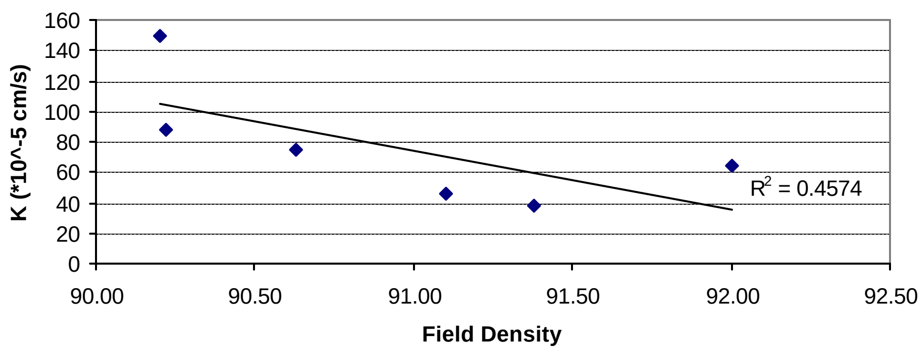


Figure 2 Field Permeability vs Field Density (Binder layer)

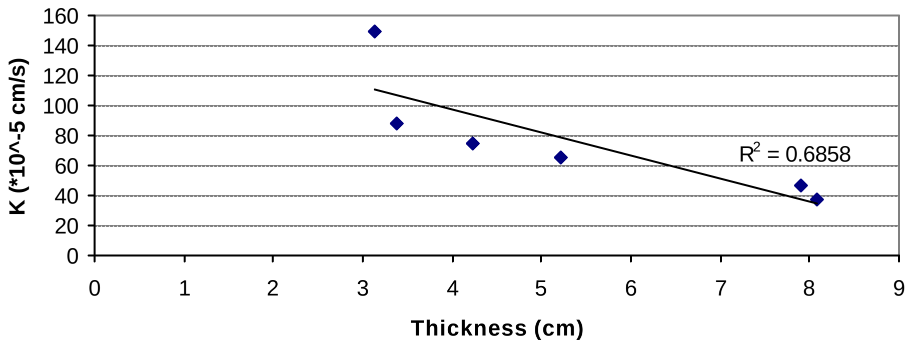


Figure 3 Field Permeability vs Thickness (cm) (Binder Layer)

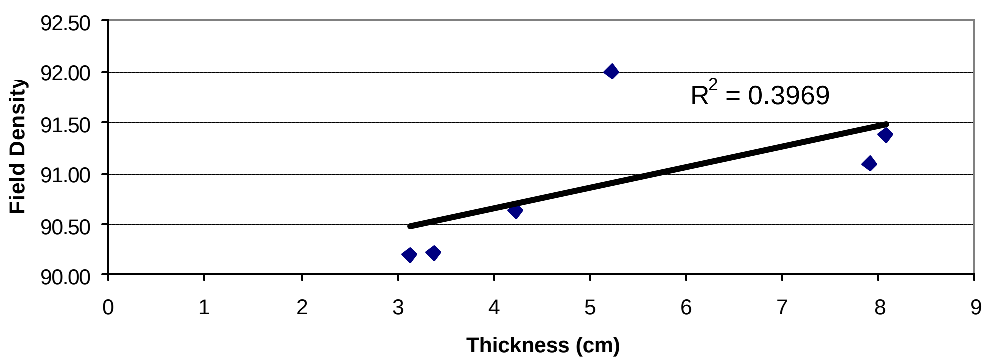


Figure 4 Field Density vs Thickness (cm) (Binder Layer)

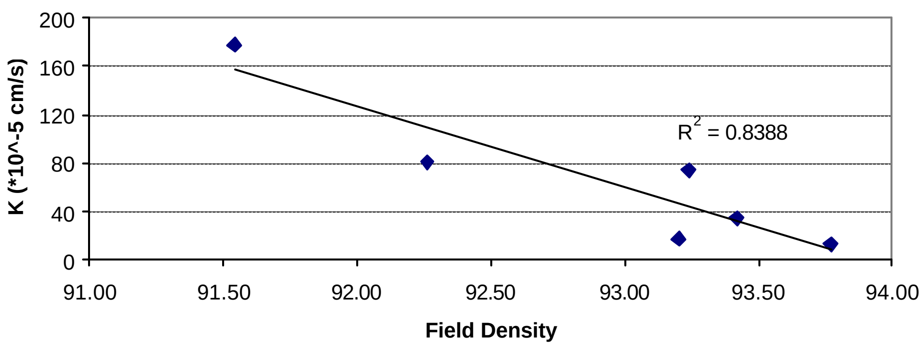


Figure 5 Field Permeability vs Field Density (Surface Layer)

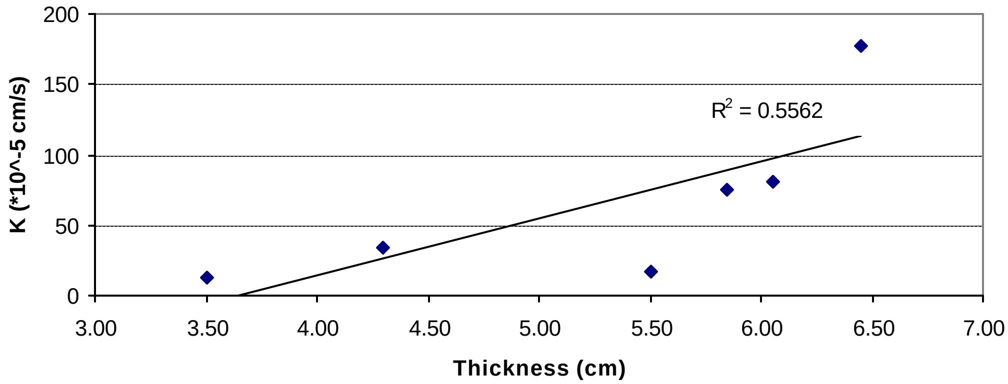


Figure 6 Field Permeability vs Thickness (cm) (Surface Layer)

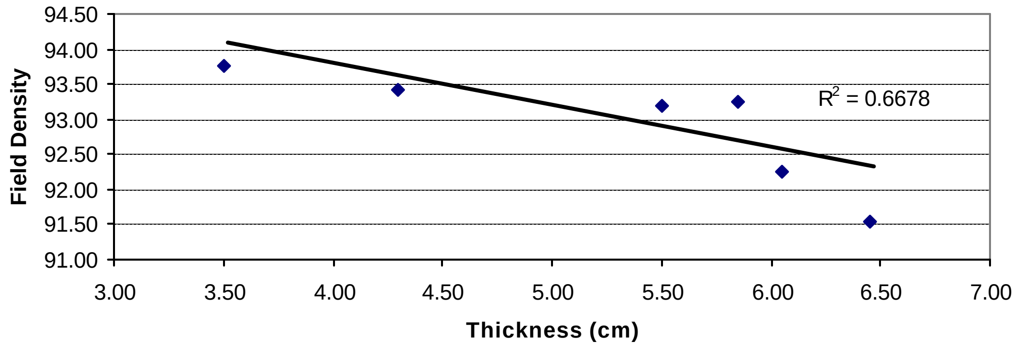


Figure 7 Field Density vs Thickness (cm) (Surface Layer)

2.3 Wisconsin Ave (Binder and Surface Layer)

- The field density and field permeability data (using NCAT device from Gilson Co.and Romus device from MU) of binder and surface layer are shown in Table 6 and 7.
- The relationships between field permeability, field density and thickness for both layers are shown in Figure 8-13.

Table 6 Summary of Field Data for Wisc Ave (Binder)

Site	BR (passes)	RR (passes)	FR (passes)	Field Density	Thickness (cm)	Field K (* 10^-5 cm/s)
3	5	2	7	94.62	7.94	72.9
4	2	3	3	90.68	6.99	46.1
5	3	1	3	93.31	6.35	186.05
6	4	1	2	90.77	5.08	406.7
8	5	2	4	92.40	4.45	21.8
9	2	1	2	90.87	5.72	151.15
14	2	1	2	83.22	5.08	2995.9
15	4	0	2	86.27	3.81	1517.3
16	4	0	2	85.36	3.18	2588.95
17	3	1	2	89.94	3.49	62.55
18	6	3	3	90.88	3.18	91.6

Table 7 Summary of Field Data for Wisc Ave (Surface)

Site	BR (passes)	RR (passes)	FR (passes)	Field Density	Thickness (cm)	Field K (* 10^-5 cm/s)
4	2	2	7	92.25	3.81	42.56
5	2	4	10	94.38	4.128	34.77
6	3	1	1	90.63	6.033	287.18
7	2	0	5	90.43	3.175	219.65
8	4	1	2	92.24	6.35	86.77
9	2	6	7	94.12	5.08	45.32

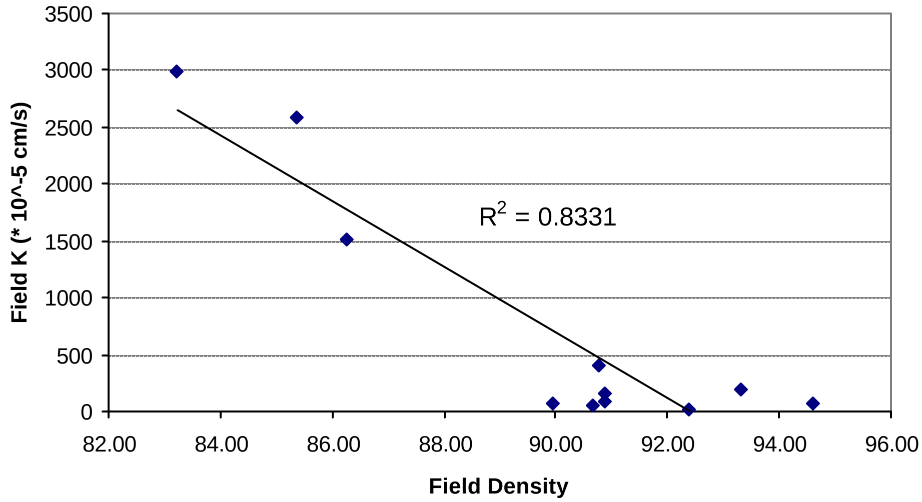


Figure 8 Field Permeability vs Field Density (Binder Layer)

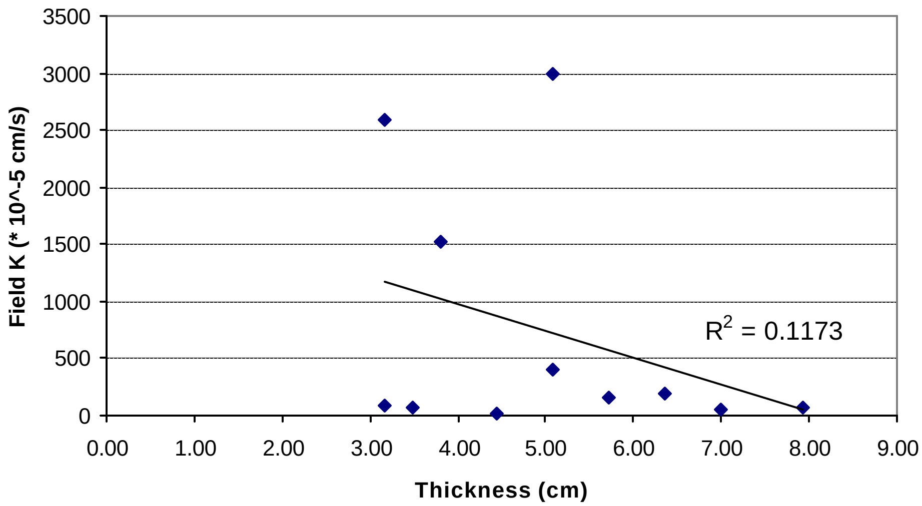


Figure 9 Field Permeability vs Thickness (cm) (Binder Layer)

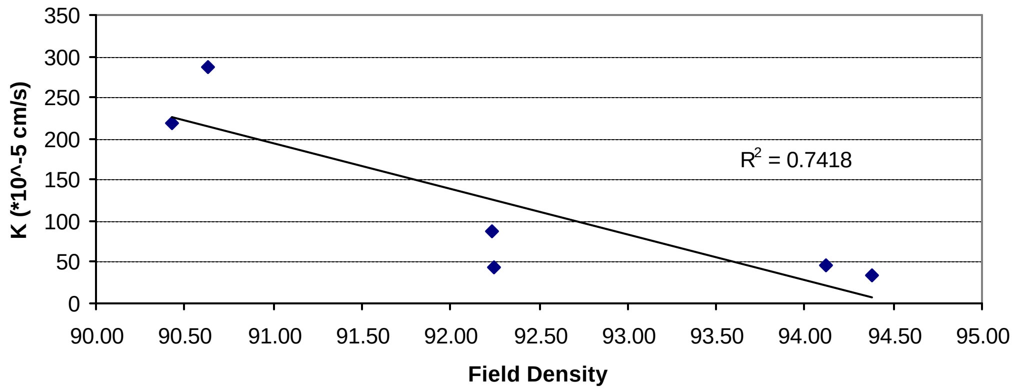


Figure 11 Field Permeability vs Field Density (Surface Layer)

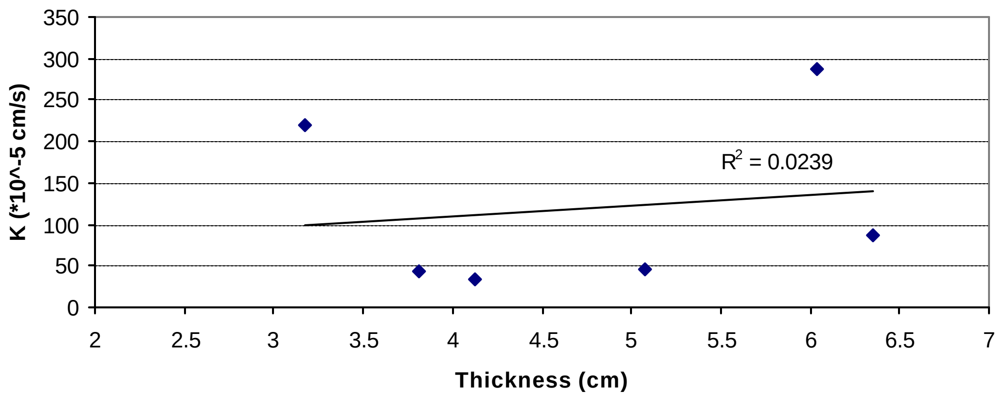


Figure 12 Field Permeability vs Thickness (cm) (Surface Layer)

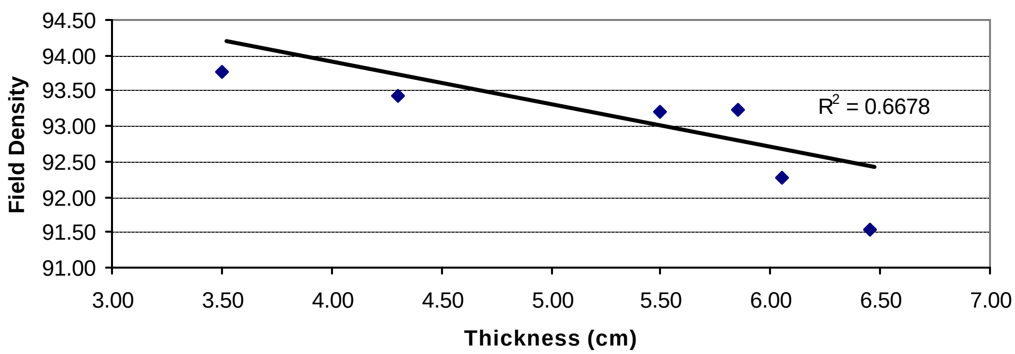


Figure 13 Field Density vs Thickness (cm) (Surface Layer)

3. **Laboratory Study Results**

I-43 (Binder Layer)

- Laboratory permeability testing for the cored samples from I-43 project was completed. The results are shown in Table 8.
- The lab partially saturated permeability and fully saturated permeability were measured. The relationship between partially saturated K, fully saturated K, and field K is shown in Figure 14.
- The relationships between field and lab permeability, lab density and thickness are shown in Figure 15-17.

Table 8 Summary of Laboratory Permeability Data for I-43 Project

Sample	Thickness (cm)	Lab Density	Partially Saturated K (cm/s)	Fully Saturated K (cm/s)	Field K (cm/s)
1-C	14.605	94.81		2.90E-06	1.48E-04
2-C	13.335	92.94	1.86E-04	6.70E-04	2.20E-03
3-C	9.525	92.72	1.49E-04	6.80E-04	1.70E-03
4-C	6.985	93.67	2.36E-04	5.40E-04	1.98E-03
5-C	6.985	93.19	3.43E-05	5.60E-04	2.66E-03
6-C	6.35	93.50	5.23E-05	5.30E-04	3.87E-03
1L					
2L					
3A-L	9.51	92.67	3.34E-04	1.00E-03	
4B-L	7.09	93.40	1.86E-04	7.20E-04	
5C-L	6.99	93.13	1.05E-05	4.10E-04	
6L					

*C = Cored sample
L = Lab compacted sample

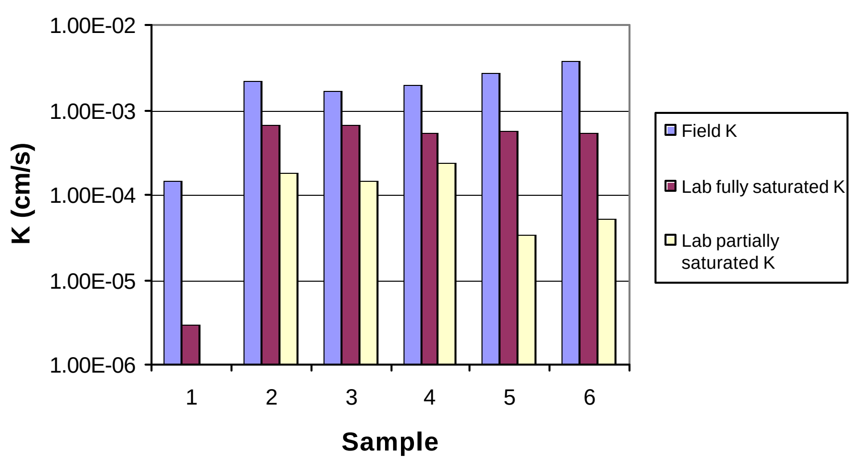


Figure 14 Relationship between Field K, Fully Saturated K, and Partially Saturated K for the Cored Samples of all 6 Test Sites

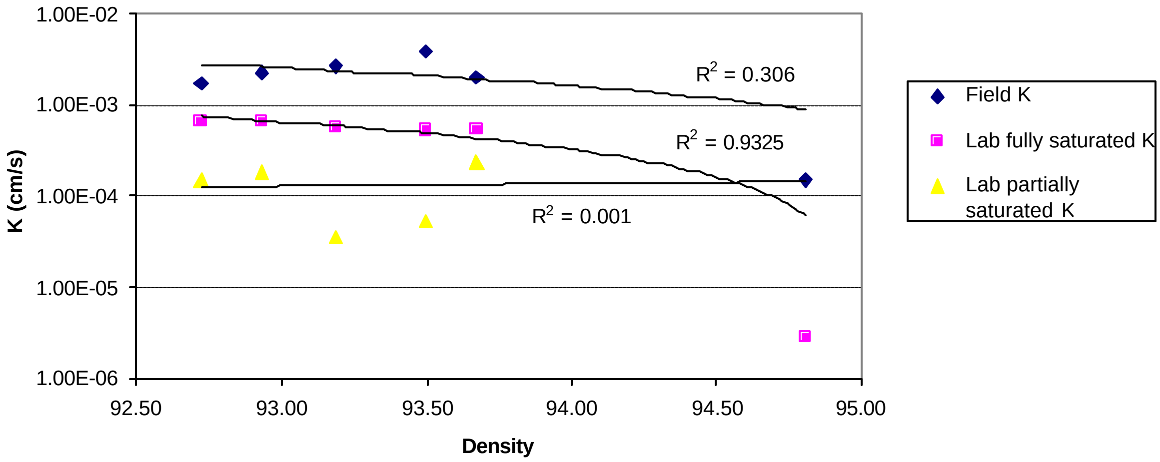


Figure 15 Permeability vs Lab Density for I-43

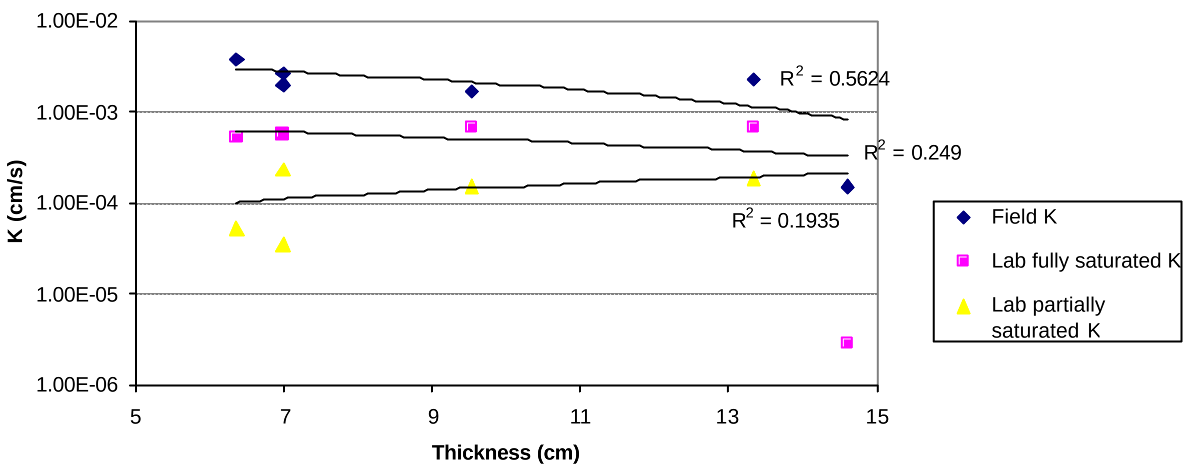


Figure 16 Permeability vs Thickness for I-43

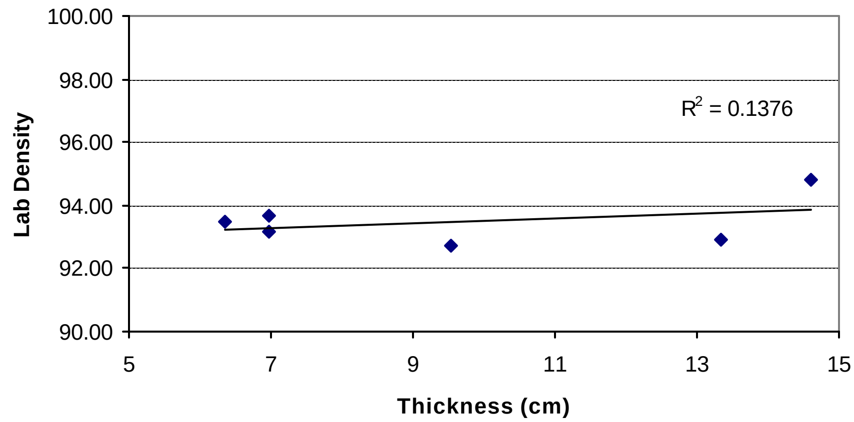


Figure 17 Lab Density vs Thickness for I-43

Work Next Quarter:

- Laboratory testing for the cored samples of the rest of the projects will be completed.
- The statistical analysis for the existing data will be performed.
- Next projects that fit the experimental matrix will be determined.
- The meeting among the team members (UW-Madison, Marquette, and UW-Platteville) will be held every two weeks.

Circumstances affecting progress/budget:

None at this time. Project progress is more than planned for.

Gantt Chart:

PROJECT I.D.0092-02-14	STARTING DATE	COMPLETION DATE	MONTH	Report#
PROJECT # WISDOT	**7-Nov-01**	**7-Nov-04**	**12-July**	**3**
CONSULTANT FIRM NAME **UW - MADISON**		% TIME ELAPSED	TOTAL PROJECT FUNDING	CONTRACT FUNDING 100%
NAME OF STUDY **THE EFFECT OF PAVEMENT THICKNESS ON SUPERPAVE MIX PERMEABILITY AND DENSITY**				

															PERCENT OF			
															PROJECT	TASK COMPLETE	TASK COMPLETE	PROJECT COMPLETE
	YEAR	2001	2002				2003				2004							
TASK *	MONTH	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 5	Qtr 6	Qtr 7	Qtr 8	Qtr 9	Qtr 10	Qtr 11	Qtr 12	Qtr 13				
TASK 1 : Review national and regional research on consistent aggregate sources															10		90	9
TASK 2 : Identify commercial HMA plants with consistent aggregate sources															8		75	6
TASK 3 : Identify project for field comparisons															8		20	1.6
TASK 4 : Evaluation of effect of directional hydraulic conductivity															10		0	0
TASK 5 : Conduct field and laboratory studies															25		15	3.75
TASK 6 : Analyze data and prepare guidelines															25		0	0
TASK 7 : Prepare and submit final report															10		0	0
Final Report review and revisions															2		0	0
Final Report Submittal															2		0	0
	Scheduled																	
	Completed														100			20.35

Note: Gantt chart shown in State Fiscal Year Quarters