Determination of Proper Mixing and Compacting Temperatures of Laboratory Fabricated Asphalt Concrete Specimens

FINAL REPORT
SPR Project No. 5263

by

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Prepared for

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in cooperation with

U.S. Department of Transportation
Federal Highway Administration
Washington D C 20590

October 1994

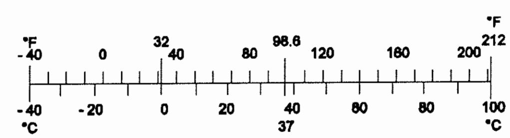
SI* (MODERN METRIC) CONVERSION FACTORS

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	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

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	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

Technical Report Documentation Page

1. Report No. FHWA-OR-RD-95-11	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Determination of Proper Mixing and Compacting Temperatures of Laboratory Fabricated Asphalt Concrete Specimens		5. Report Date April 1995 6. Performing Organization Code
7. Author(s) Dan Sosnovske		8. Performing Organization Report No.
9. Performing Organization Name and Address Research Unit Engineering Services Section Oregon Department of Transportation 2950 State Street Salem OR 97310		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR #5263
12. Sponsoring Agency Name and Address Oregon Department of Transportation and Federal Highway Administration Research Unit, 400 Seventh Street S W 2950 State Street, Washington D C 20590 Salem OR 97310		13. Type of Report and Period Covered Final Report 1994-1995 14. Sponsoring Agency Code HTA-21
15. Supplementary Notes		

16. Abstract

The Oregon Department of Transportation (ODOT) Materials Unit has historically used one temperature for the mixing and compacting of laboratory fabricated asphalt concrete specimens. Since switching to the performance based asphalt (PBA) specifications in 1991, the Bituminous Design Crew has continued to use the same specimen preparation technique. However, the method of recommending mixing and lay-down temperatures for construction relies on a viscosity based system.

The objectives of this study are to evaluate the differences in physical properties between specimens prepared using the constant temperature technique and a viscosity based temperature selection technique. The physical properties analyzed are: air void content, Hveem stability, Index of Retained Modulus and Index of Retained Strength.

Because of the small sample size and the small differences in the mixing and compacting temperatures used in this study, no difference in physical properties could be identified for the two temperature selection methods. It is recommended that the Materials Unit adopt the viscosity based temperature selection method in anticipation of switching to the SHRP PG asphalt grading system and the SHRP gyratory method of compaction.

17. Key Words ASPHALT, TEMPERATURE, VISCOSITY, MIX DESIGN, ASPHALT CONCRETE, CONSTRUCTION		18. Distribution Statement Available from the Research Unit of the Oregon Department of Transportation	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72)Reproduction of completed page authorized

ACKNOWLEDGEMENTS

The author would like to thank the following people for their support in completing this project: The Bituminous Mix Design Crew for their help in preparing and testing the specimens, Liz Hunt, Keith Martin and Wes Heidenreich and the technical advisory committee for there efforts in reviewing and editing the report and Lauri Kroeker for her help in formatting and typing the final manuscript.

DISCLAIMER

Proper Mixing and Compaction Temperatures of Lab Compacted Asphalt Concrete Specimens

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1.0 INTRODUCTION

1.1 BACKGROUND

The Oregon Department of Transportation (ODOT) Bituminous Design Crew has two procedures for fabricating asphalt concrete specimens. The procedures are from the ODOT Laboratory Manual of Test Procedures (1986), test method 302-86 for the fabrication of kneading compacted specimens, and test method 307C-86 for the fabrication of statically compacted specimens.

Test method 307C-86 is a modified AASHTO T-167 procedure. The method requires that only one temperature be used for the mixing of all specimens, regardless of the grade of asphalt cement. A constant compaction temperature is also utilized.

The ODOT test method 302-86 is the AASHTO T-247 test method. AASHTO T-247 specifies different mixing temperatures for the different viscosity grades of asphalt cement. Historically, ODOT has primarily used an AC-15 or AC-30 graded asphalt cement. For these two grades, the 302-86 (T-247) temperatures are the same. Coincidentally, the temperature used for test method 307C-86 and 302-86 is the same, 135°C (275°F) for mixing and 124°C (255°F) for compacting. These temperatures have continued to be used in the lab for fabricating asphalt concrete specimens even though ODOT switched to a Performance Based Asphalt (PBA) specification in 1991. When making recommendations for construction mixing and laydown temperatures, however, the Bituminous Design Crew uses a viscosity based technique to determine the temperature.

1.2 OBJECTIVES

This project evaluated the differences in physical properties between samples prepared using a constant-temperature preparation technique and a viscosity based temperature selection technique. The information from the study will be used to determine the most appropriate method for lab sample preparation and corresponding construction mixing and compaction temperature recommendations.

The viscosity based technique used an equiviscous temperature based on the viscosity of 170 $\pm$ 20 cSt for mixing and 280 $\pm$ 30 cSt for compaction. The constant-temperature method used 135$\pm$3°C (275$\pm$5°F) for mixing and 124$\pm$3°C (255 $\pm$ 5°F) for compaction. For each temperature selection technique, the physical properties of the mixtures such as bulk and maximum specific gravity, air void percentage, Hveem stability, Index of Retained Strength and Index of Retained Resilient Modulus are evaluated.

2.0 LITERATURE REVIEW

A literature review was performed to identify any possible sources of information related to the objectives of the project. This chapter outlines the results of the literature review.

Several online searches executed through the ODOT library uncovered very little information regarding this subject. However, two separate journal articles shed some light in this area.

From a study conducted in 1971 at the University of Texas at Austin the following conclusion was made:

> *The effect of compaction temperature could explain some of the differences observed in the past between the field results, because most laboratory procedures involve preparation of materials at certain fixed compaction temperatures. If the mixtures are compacted in the field at temperatures much different than those used in laboratory tests, then certainly, as evidenced by the results of the study, the mixture cannot be expected to perform in the field as predicted in the laboratory (Hadley et al., 1971).*

The results of this study demonstrate the importance of temperature in the preparation of laboratory specimens as well as in the construction of asphalt concrete pavements. If the temperatures are not the same, significant differences in the field performance could occur.

The second study, by Kennedy et al., 1984, refers to the previous study by mentioning the following:

> *The results indicated that compaction temperature along with asphalt content, grade of asphalt cement, and aggregate gradation, had a significant effect on tensile strength. In fact the results were dominated by compaction temperature, which not only produce the largest effect but also tended to interact with other variables.*

The conclusions from Kennedy's study state the following:

> *...there is an apparent effect of compaction temperature on engineering properties. Tensile strength, static and resilient moduli, Marshall stability, and to a lesser extent Hveem stability of asphalt mixtures are reduced when compaction occurs at lower temperatures.*
>
> *If lower mixing and thus compaction temperatures are anticipated in the field, it is recommended that the effect of these lower temperatures be evaluated in terms of engineering properties and thus performance.*

It is apparent that changing the mixing and compaction temperatures of asphalt concrete mixtures in the laboratory can greatly affect the measured properties. This also points out the need to specify construction temperatures so they correspond to the temperatures being used in the lab. If field temperatures differ from the lab temperatures the material properties achieved in the field may be less than desired.

3.0 LABORATORY STUDY

3.1 EXPERIMENT DESIGN

3.1.1 Materials Used

The testing program was designed to utilize two different sources of aggregate and four different grades of the PBA binder. The aggregate utilized was from Riverbend Sand and Gravel (Hilroy #24-2-2) and a mixture from the Coffee Lake (#34-098-2) and Reed Pit (#24-023-2) sources. The aggregate mix design gradations are listed in Table 3.1.

Table 3.1 Mix Design Gradations

Sieve Size	Mix Gradations - Percent Passing	
	Coffee Lake/Reed	Riverbend
1"	100	100
3/4"	95.3	95.6
1/2"	80.3	81.7
3/8"	68.7	68.9
1/4"	54.5	56.1
#4	46.3	48.7
#10	27.6	29.3
#40	10.6	11.1
#200	4.0	3.7

The asphalt used for the project included PBA-2, PBA-3 and PBA-6 from Chevron and PBA-5 from McCall Oil. The asphalt properties are listed in Table 3.2.

3.1.2 Testing Scheme

Four different standard laboratory tests were used to determine if there was a difference in mixture properties for the two mixing techniques (viscosity based and fixed temperature). These tests were air voids of the specimens (bulk and maximum specific gravities), Hveem Stability, Index of Retained Strength and Index of Retained Modulus.

Table 3.2 Asphalt Properties

	ORIGINAL PROPERTIES	AGED (RTF) PROPERTIES
Chev PBA-2 February 1, 1994	o Absolute Viscosity (140°F) = 1610 P o Kinematic Viscosity (275°F) = 394 cSt	o Absolute Viscosity (140°F) = 3770 P o Kinematic Viscosity (275°F) = 575 cSt o Pen @ 39.2°F = 25 dmm o Ductility @ 77°F = 132 cm o Viscosity Ratio = 2.3 o Loss % Weight = 0.11%
Chev PBA-3 February 1, 1994	o Absolute Viscosity (140°F) = 3520 P o Kinematic Viscosity (275°F) = 545 cSt	o Absolute Viscosity (140°F) = 7600 P o Kinematic Viscosity (275°F) = 760 cSt o Pen @ 39.2°F = 39 dmm o Ductility @ 77°F = 100+ cm o Viscosity Ratio = 2.2 o Loss % Weight = 0.19%
McCall PBA-5 January 27, 1994	o Absolute Viscosity (140°F) = 2660 P o Kinematic Viscosity (275°F) = 434 cSt	o Absolute Viscosity (140°F) = 6290 P o Kinematic Viscosity (275°F) = 615 cSt o Pen @ 39.2°F = 19 dmm o Ductility @ 77°F = 100+ cm o Viscosity Ratio = 2.4 o Loss % Weight = 0.15%
Chev PBA-6 February 1, 1994	o Absolute Viscosity (140°F) = 36700 P o Kinematic Viscosity (275°F) = 735 cSt	o Absolute Viscosity (140°F) = 42600 P o Kinematic Viscosity (275°F)= 1040 cSt o Pen @ 39.2°F = 40 dmm o Ductility @ 77°F = 100+ cm o Viscosity Ratio = 1.2 o Loss % Weight = 0.16%

Table 3.3 outlines the number of specimens used for each test procedure. The bulk specific gravity (ODOT TM-302A-86) was determined for each specimen. In addition, the Rice specific gravity (ODOT TM-306-86) was determined for one specimen at each asphalt content and aggregate combination. These tests enabled the air void content of all specimens to be calculated.

Table 3.3 Testing Scheme

Test	# of Specimens	# of Asphalt Contents
Hveem Stability	6	3
IRS	4	1
IRMr	2	1
Air Voids	All Above	

3.2 SPECIMEN PREPARATION

The specimens used for this project were fabricated at the ODOT Materials Unit laboratory in Salem. As per the project objectives, two different preparation techniques were used. The first was the traditional technique (fixed mixing temperature) currently used by the lab. The second was the viscosity based temperature technique. The following section describes both procedures.

3.2.1 Traditional Method

The traditional mix design approach currently used by the ODOT Bituminous Crew utilizes one temperature for the mixing and compacting of all specimens. The mixing temperature is set at 135±°C (275 ± 5°F), and the compaction temperature is set at 124±3°C (255 ± 5°F). A viscosity based temperature selection method is used to determine the recommended mixing and lay-down temperatures for construction.

3.2.2 Viscosity Based Technique

The viscosity based technique varies the mixing and compaction temperature based on the viscosity of the asphalt cement used. The basic asphalt lab data is input into a computer program that estimates the mixing and compaction temperature using set viscosity criteria. This is the same program that is used to recommend the mixing and lay-down temperature for the construction of asphalt concrete pavements. The viscosity criteria uses an equiviscous temperature of 170 ± 20 cSt for mixing and 280 ± 30 cSt for compaction. The temperatures used for this investigation are outlined in Table 3.4.

Table 3.4 Temperatures Used in Study.

	Viscosity-Based Temperature		Constant Temperature	
	Mixing °C (°F)	Compacting °C (°F)	Mixing °C (°F)	Compacting °C (°F)
PBA-2	151.6 (305)	141.7 (287)	135 (275)	124 (255)
PBA-3	157.2 (315)	146.7 (296)	135 (275)	124 (255)
PBA-5	152.7 (307)	143.3 (290)	135 (275)	124 (255)
PBA-6	157.7 (316)	149.4 (301)	135 (275)	124 (255)

4.0 TEST METHODS AND RESULTS

4.1 AIR VOIDS AND SPECIFIC GRAVITIES

The bulk specific gravity of all specimens was determined in the ODOT Bituminous Materials Lab according to ODOT TM-302A-86 (AASHTO T-166 method B). The maximum specific gravities were measured according to ODOT TM-306-86 (AASHTO T-209, flask method) and percent air voids were calculated for each specimen. The results are presented in Tables 4.1 - 4.4, and Figures 4.1 - 4.4. A summary of data is presented in Appendix A.

A statistical evaluation was performed on the data to determine if there was a statistical difference in air void contents for specimens prepared by each method. It is apparent that at the 99 percent confidence level there is no difference in the mixture properties for all levels of temperature. However, when evaluated at the 95 percent level, four of the eight mixture combinations were found to show a difference in air void content at the different temperature levels. The mixtures showing the differences were as follows: both PBA-6 mixtures, PBA-5 - Riverbend and PBA-3 - Coffee Lake/Reed.

The statistical analysis also demonstrated that there was significant difference at the 99 percent level for all mixture combinations for the asphalt content effect on air voids.

4.2 HVEEM STABILITY

The Hveem stability (ODOT TM-303-86) was measured on six specimens for each mixture combination: two each, at three different asphalt contents. Asphalt contents were at the optimum asphalt content, 0.5% over optimum and 0.5% below optimum. The optimum asphalt content was determined from a previous mixture design done by the Bituminous Crew. The results from the stability tests are presented graphically in Figures 4.5 - 4.8.

A statistical evaluation was performed on the data. From this analysis, it is apparent that at the 95 percent confidence level, only one mixture combination shows a significant difference in the stability values. The other combinations do not show a statistically significant difference.

4.3 INDEX OF RETAINED STRENGTH

The Index of Retained Strength (IRS) test utilized four specimens. Two of the specimens tested were unconditioned and two were conditioned as prescribed by ODOT TM-308-86 (AASHTO T-165). These specimens contained the optimum asphalt content as described above. For this test, specimens with a 100-mm (4-inch) height were required. Specimens were compacted using a static method of compaction (ODOT TM-307C-86).

Table 4.1 PBA-2, Air Void Summary

Mix	AC, %	Average Air Voids, % Standard	Average Air Voids, % Viscosity
PBA -2 Riverbend	4.8	6.8	6.7
	5.3	5.7	5.7
	5.8	3.6	3.6
PBA-2 Coffee/Reed	5.1	5.6	7.4
	5.6	4.1	4.3
	6.1	2.3	2.5

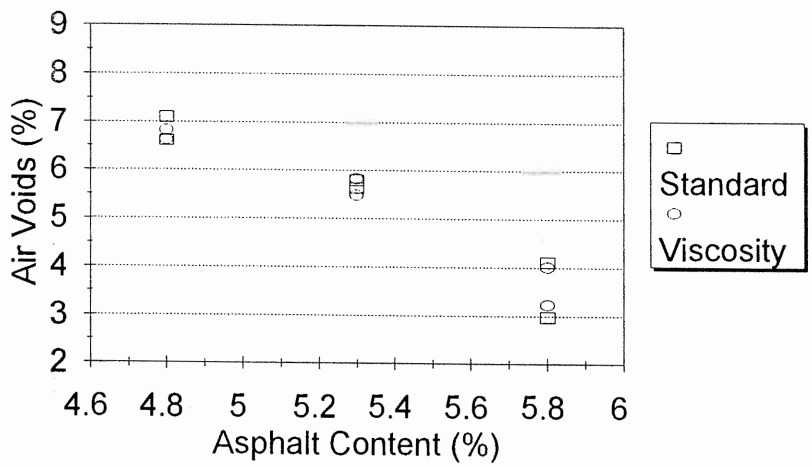

Figure 4.1(a). Air Voids vs. Asphalt Content, PBA-2, Riverbend

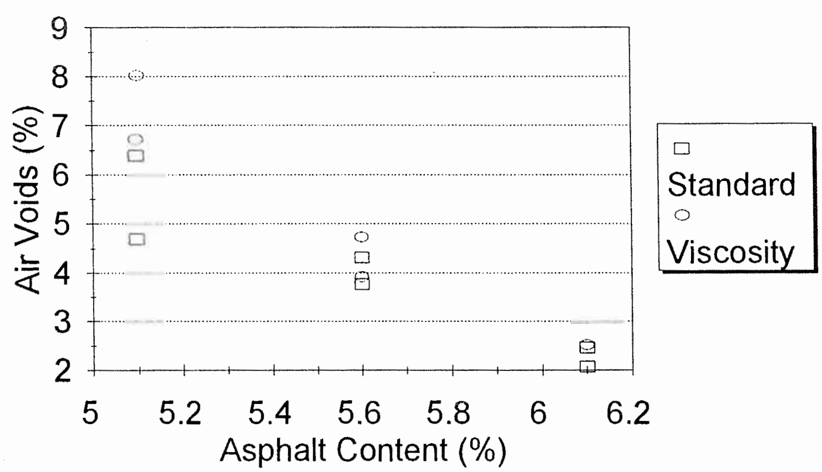

Figure 4.1(b). Air Voids vs. Asphalt Content, PBA-2, Coffee Lake/Reed

Table 4.2 PBA-3, Air Void Summary

Mix	AC, %	Average Air Voids, % Standard	Viscosity
	4.8	7	7
PBA -3	5.3	5.3	5.8
Riverbend	5.8	3.9	3.6
	5.1	5.6	5.4
PBA-3	5.6	3.4	4.5
Coffee/Reed	6.1	2.8	3.4

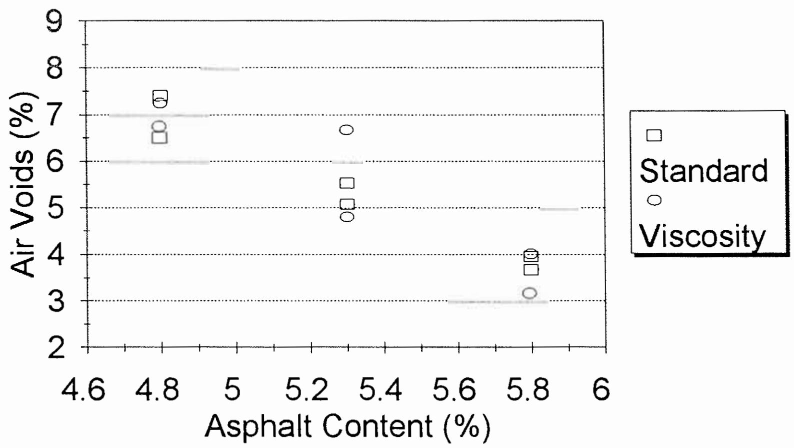

Figure 4.2(a). Air Voids vs. Asphalt Content, PBA-3, Riverbend

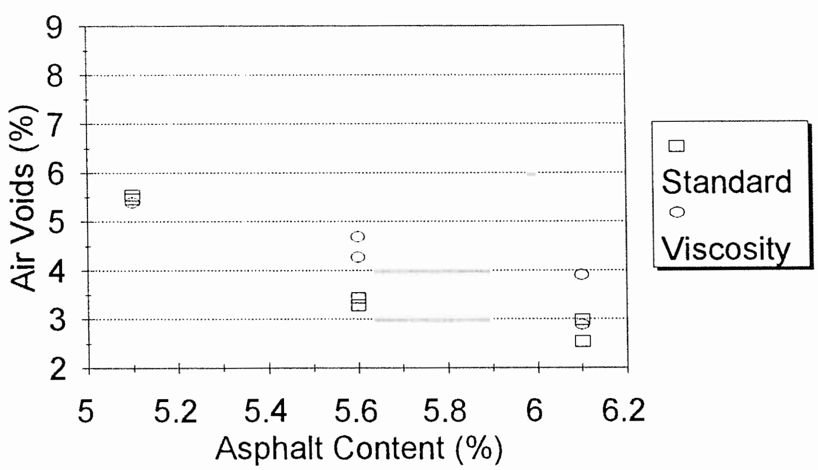

Figure 4.2(b). Air Voids vs. Asphalt Content, PBA-3, Coffee Lake/Reed

Table 4.3 PBA-5, Air Void Summary

Mix	AC, %	Average Air Voids, % Standard	Viscosity
PBA -5 Riverbend	4.8	6.6	7.1
	5.3	4.9	5.2
	5.8	3.8	4.2
PBA-5 Coffee/Reed	5.1	5	5.5
	5.6	4.4	4.3
	6.1	2.6	2.9

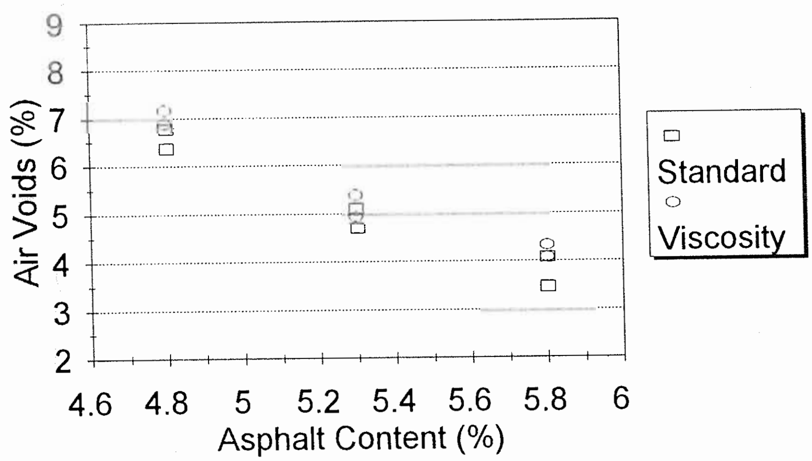

Figure 4.3(a). Air Voids vs. Asphalt Content, PBA-5, Riverbend

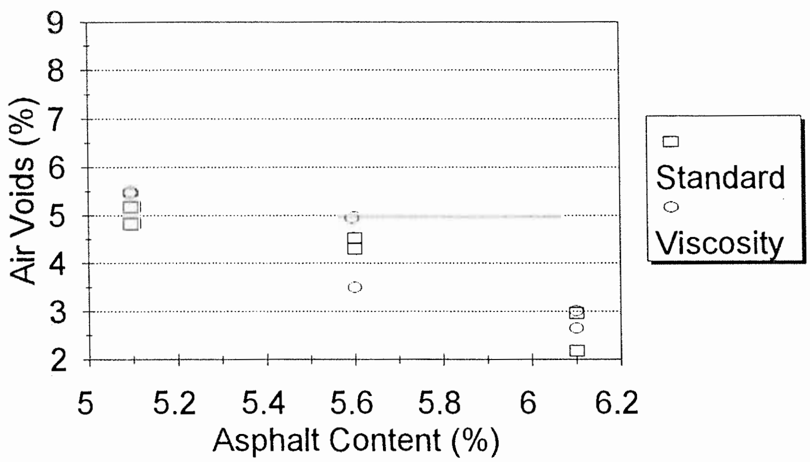

Figure 4.3(b). Air Voids vs. Asphalt Content, PBA-5, Coffee Lake/Reed

Table 4.4 PBA-6, Air Void Summary

Mix	AC, %	Average Air Voids, %	
		Standard	Viscosity
PBA -6 Riverbend	4.8	7.4	6.9
	5.3	5.6	4.6
	5.8	4.7	3.1
PBA-6 Coffee/Reed	5.1	5.9	4.7
	5.6	4.1	3.9
	6.1	3	2.2

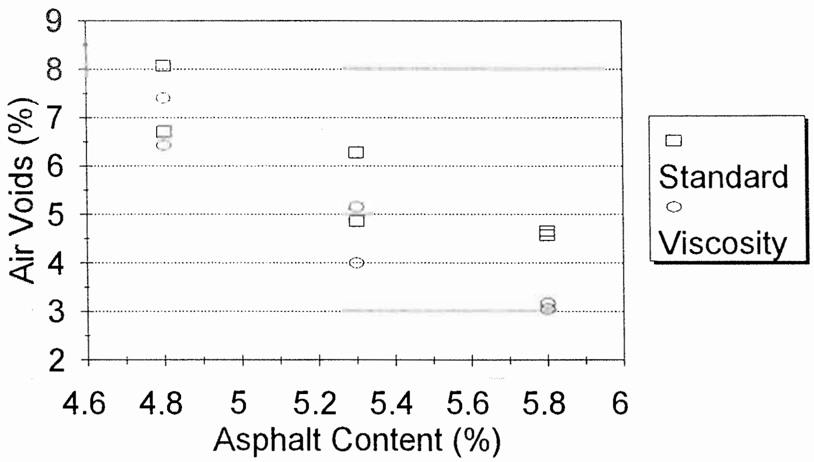

Figure 4.4(a). Air Voids vs. Asphalt Content, PBA-6, Riverbend

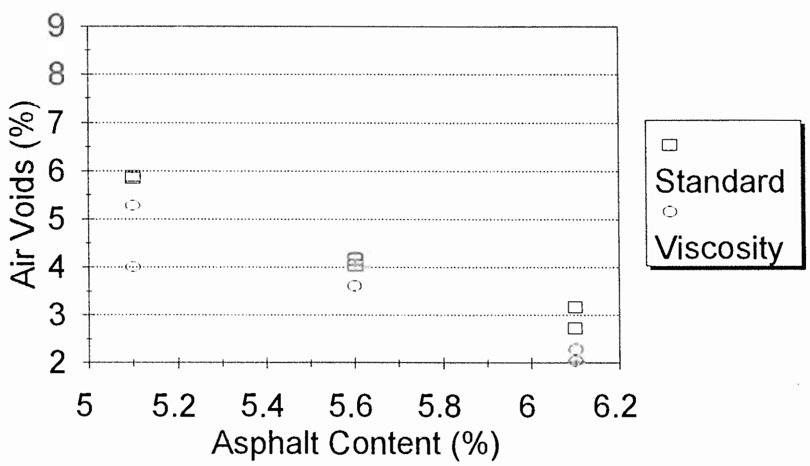

Figure 4.4(b). Air Voids vs. Asphalt Content, PBA-6, Coffee Lake/Reed

Difference in the values for the IRS for the different asphalt types and the different mixture temperatures were apparent. No distinct trend, however, in which temperature selection technique results in a greater or lesser retained strength was determined. The results from the IRS tests are shown graphically in Figure 4.9.

4.4 INDEX OF RETAINED MODULUS

The Index of Retained Modulus (IRMr) test procedure (ODOT TM-315-90) required two specimens. Specimens were prepared at the optimum asphalt content described above. IRMr required 64-mm (2.5-inch) high specimens compacted using the kneading compactor.

The results for the Retained Modulus test are presented in Figure 4.10. From these graphs the results seem to be mixed. For the Riverbend aggregate the standard mixing temperature appears to result in higher values. However, the Coffee Lake/Reed aggregate seems to demonstrate higher values with the viscosity based temperatures.

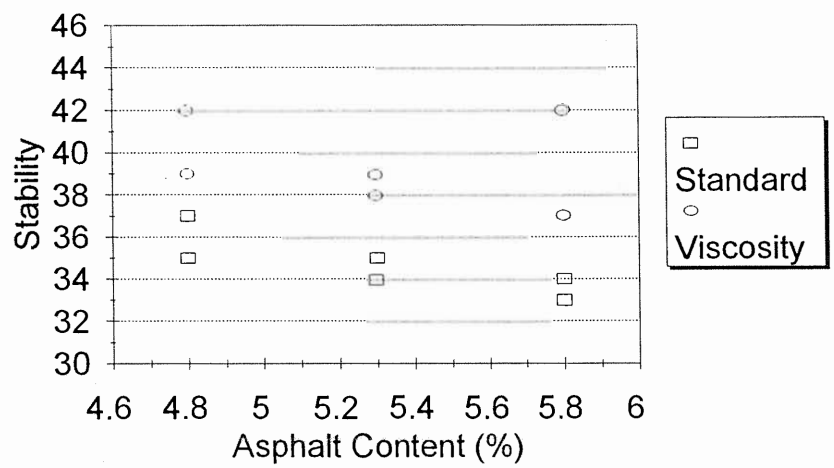

Figure 4.5(a). Stability vs. Asphalt Content, PBA-2, Riverbend

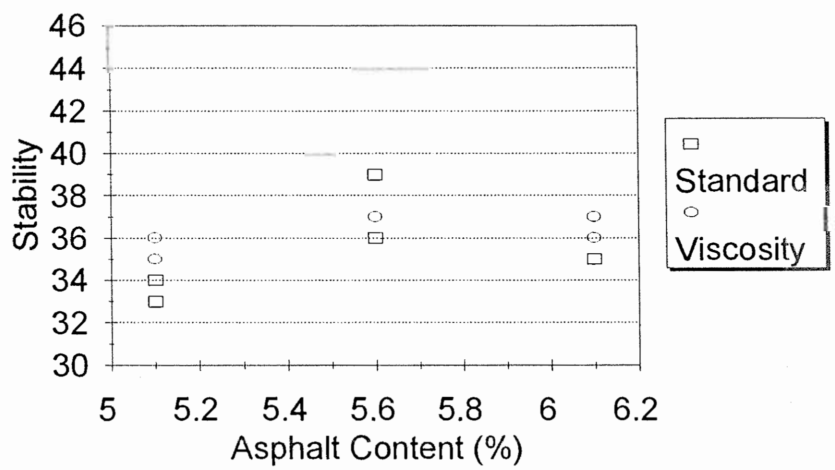

Figure 4.5(b). Stability vs. Asphalt Content, PBA-2, Coffee Lake/Reed

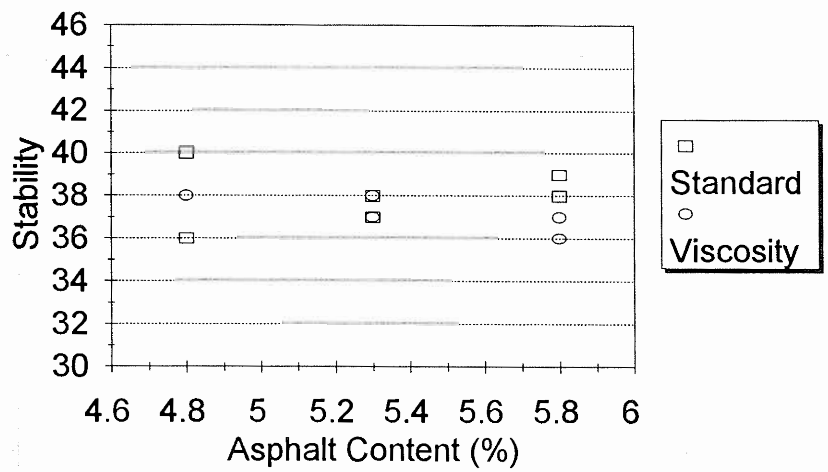

Figure 4.6(a). Stability vs. Asphalt Content, PBA-3, Riverbend

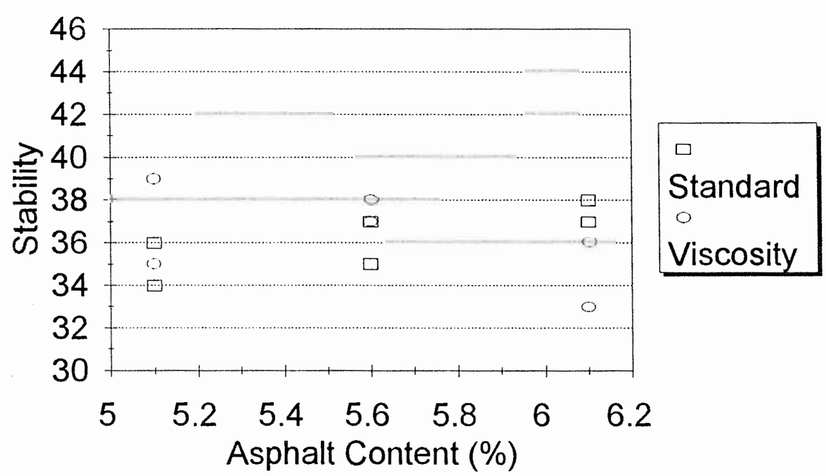

Figure 4.6(b). Stability vs. Asphalt Content, PBA-3, Coffee Lake/Reed

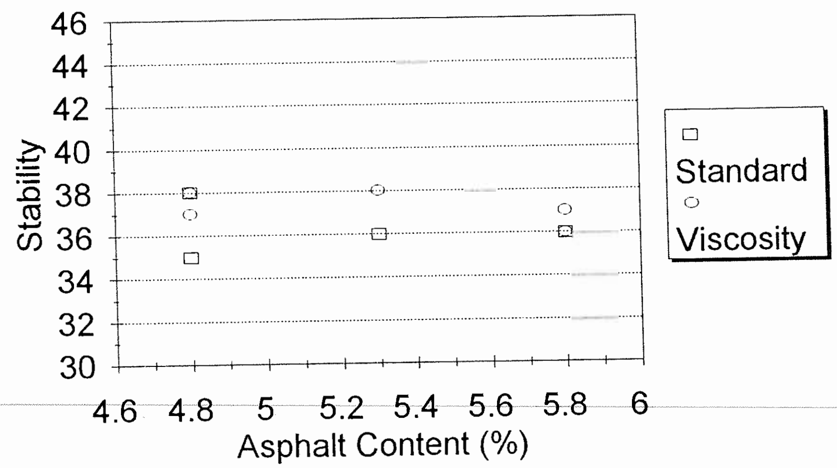

Figure 4.7(a). Stability vs. Asphalt Content, PBA-5, Riverbend

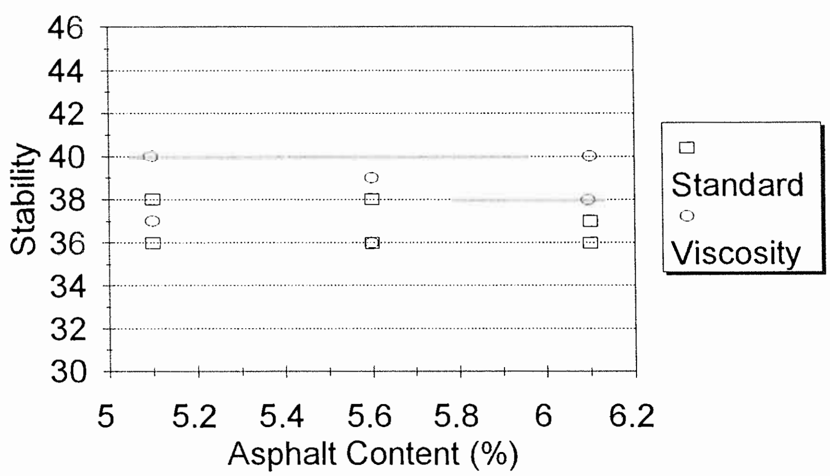

Figure 4.7(b). Stability vs. Asphalt Content, PBA-5, Coffee Lake/Reed

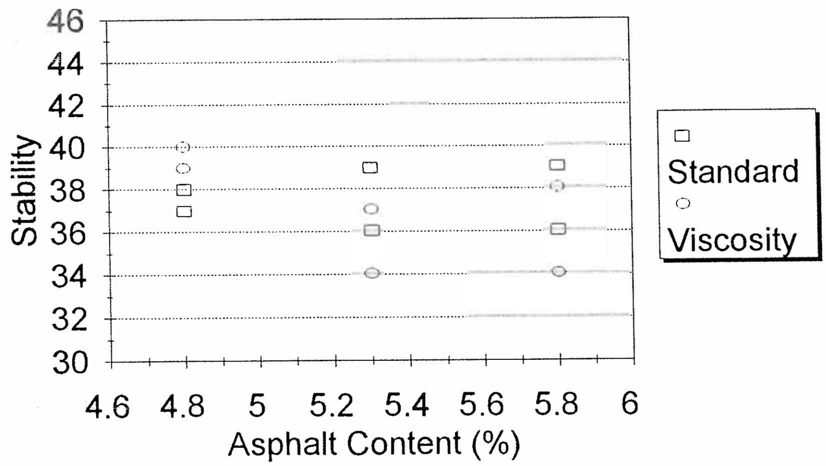

Figure 4.8(a). Stability vs. Asphalt Content, PBA-6, Riverbend

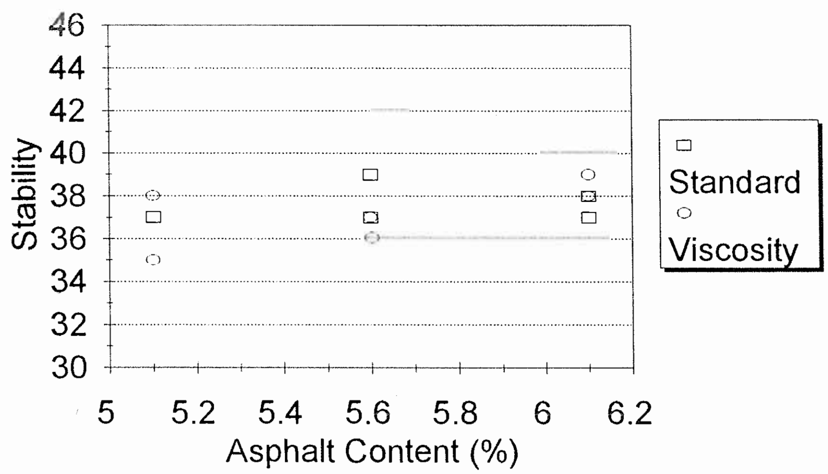

Figure 4.8(b). Stability vs. Asphalt Content, PBA-6, Coffee Lake/Reed

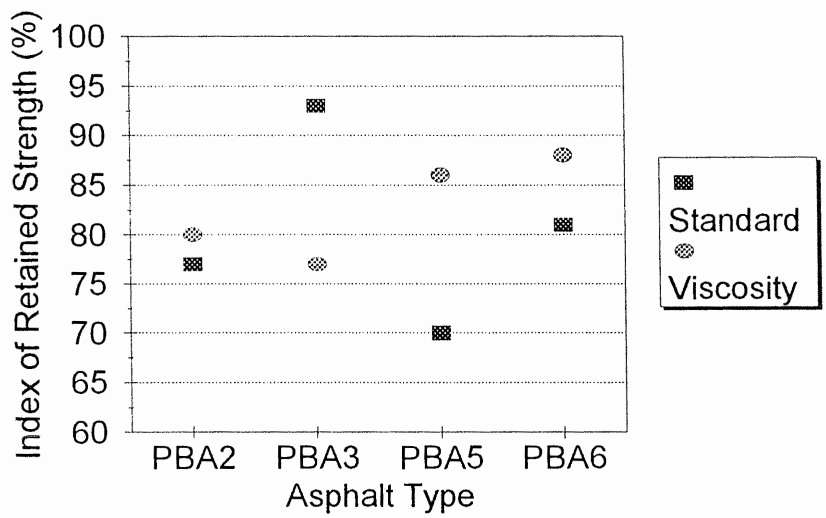

Figure 4.9(a). IRS vs. Asphalt Type, Riverbend

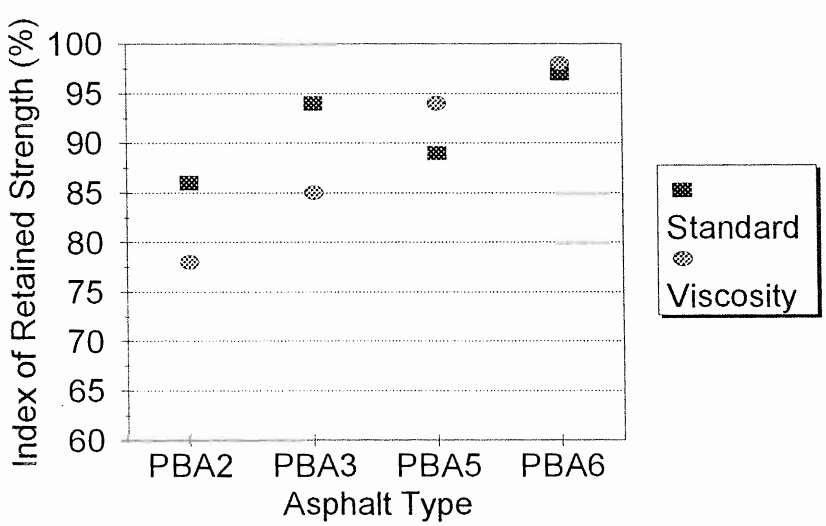

Figure 4.9(b). IRS vs. Asphalt Type, Coffee Lake/Reed

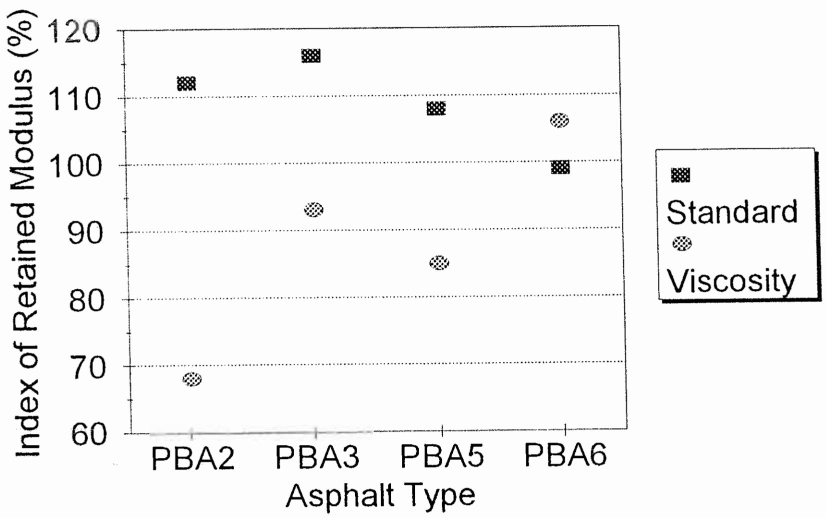

Figure 4.10(a). IRMr vs. Asphalt Type, Riverbend

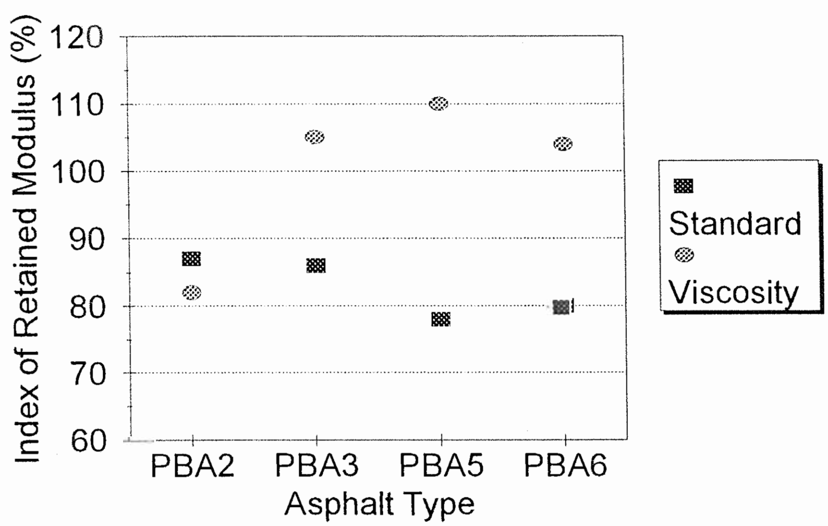

Figure 4.10(b). IRMr vs. Asphalt Type, Coffee Lake/Reed

5.0 CONCLUSIONS AND RECOMMENDATIONS

This project was designed to evaluate the differences between a constant temperature specimen preparation technique and a viscosity-based temperature selection technique. Based on the literature review and the laboratory test results the following conclusions and recommendations for implementation are offered.

5.1 CONCLUSIONS

Information presented in Chapter 2, Literature Review, emphasized that previous studies had determined mixing and compacting temperatures play a critical role in the physical properties of the compacted mixtures. However, for the narrow range of temperatures and the relatively small sample size used in this study, it appears that there is little or no difference between the two temperature selection techniques in the compacted material properties for the materials selected for testing. For the tests performed, the results were similar across the material types or, the two methods had mixed results. If a wider range of temperatures had been tested, results similar to those in the literature review may have occurred.

Based on the information in the literature review, there is strong evidence to support the viscosity based temperature selection method. This method will more closely resemble the method ODOT uses to select construction temperatures for asphalt concrete paving. This will allow the Bituminous Mix Design Crew to perform the laboratory mix design tests on material that more closely resemble material actually placed in the field.

5.2 RECOMMENDATIONS

It is recommended that the bituminous materials lab adopt the viscosity based temperature selection technique. This method will:

- streamline the conversion to the SHRP PG asphalt grading system and the SHRP gyratory compaction procedure which will require temperature selection based on asphalt viscosities,

- standardize the temperature selection technique for the laboratory and field, to eliminate the possibility of differing material properties between the laboratory predictions and field performance,

- standardize the ODOT Bituminous lab process with other testing labs.

6.0 REFERENCES

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3. Roberts, F.L., Kandhal, P.S., Brown, E.R., Lee, D., Kennedy, T.W., *Hot Mix Asphalt Materials, Mixture Design and Construction*, First Edition, 1991. NAPA Education Foundation, Lanham, Maryland.

4. Whiteoak, D., *The Shell Bitumen Handbook*, Shell Bitumen U.K., 1990.

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Appendix

Summary Data

Project: Temp-Vis Research
Mix #: 94-13
Mix Date: 3/8/94
Aggregate: Riverbend
Asphalt: Chev PBA-2

Mix #: 94-24
Mix Date: 3/13/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	279	285	294	281	281	285	292	284	280	280	279	284	305	305	308	305	306	305	305	305	305	305	305	305
Comp Temp (°F)	260	255	257	255	255	255	260	255	255	255	256	255	287	287	288	286	286	286	287	287	287	287	287	287
Asphalt %	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3
Film Thick	suff	suff	suff-th	suff-th	th	th	th	th	th	th	th	th	suff	suff	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0+	0+	0+	0+	0+	0+					1	0+	0	0	0	0	1	1					0	0
Height (in.)	2.58	2.6	2.58	2.58	2.57	2.56	4.11	4.11	4.09	4.10	2.56	2.57	2.47	2.46	2.46	2.45	2.44	2.43	4.09	4.11	4.05	4.10	2.46	2.42
Specific Grav.	2.313	2.301	2.326	2.322	2.379	2.351	2.223	2.230	2.239	2.234			2.432	2.437	2.437	2.446	2.465	2.485	2.234	2.226	2.255	2.230		
Rice Grav.	2.477	2.477	2.465	2.465	2.452	2.452	2.465	2.465	2.465	2.465			2.610	2.610	2.588	2.588	2.568	2.568	2.588	2.588	2.588	2.588		
Air Voids %	6.6	7.1	5.6	5.8	3.0	4.1	9.8	9.5	9.2	9.4			6.8	6.6	5.8	5.5	4.0	3.2	13.7	14.0	12.9	13.8		
Stability	34	35	33	34	32	33							43	40	40	39	38	43						
Adj. Stability	35	37	34	35	33	34							42	39	39	38	37	42						
Compress Str. (psi)							3360	3440	2610	2620									3420	3320	2730	2650		
IRS %							78	76											80	80				
MR1 (ksi)											428	432											458	506
MR2 (ksi)											442	524											323	324
IRMR %											103	121											71	64

Project: Temp-Vis Research
Mix #: 94-14
Mix Date: 3/8/94
Aggregate: Coffee Lake - Reed
Asphalt: PBA-2

Mix #: 94-25
Mix Date: 3/13/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	280	280	280	280	280	292	280	287	285	280	281	276	315	306	310	308	310	305	305	305	305	305		305
Comp Temp (°F)	255	255	255	257	255		258	255	255	255	258		290	289	288	287	287	287	288	287	287	287		288
Asphalt %	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6
Film Thick	th	th	th-th	th-th	th-th+	th-th+	th	th	th	th	th	th	th	th	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0+	0+	1	1+	2+	3					1+	1+	0	0	0	0	1	2						0+
Height (in.)	2.41	2.51	2.45	2.46	2.41	2.42	3.86	3.87	3.87	3.87	2.45	2.42	2.59	2.64	2.56	2.56	2.53	2.54	3.87	3.88	3.88	3.87	2.40	2.55
Specific Grav.	2.473	2.429	2.475	2.461	2.506	2.496	2.378	2.379	2.383	2.383			2.302	2.270	2.334	2.354	2.368	2.368	2.373	2.371	2.378	2.377		
Rice Grav.	2.595	2.595	2.572	2.572	2.559	2.559	2.572	2.572	2.572	2.572			2.468	2.468	2.450	2.450	2.429	2.429	2.450	2.450	2.450	2.450		
Air Voids %	4.7	6.4	3.8	4.3	2.1	2.5	7.5	7.5	7.3	7.3			6.7	8.0	4.7	3.9	2.5	2.5	3.1	3.2	2.9	3.0		
Stability	36	33	40	37	37	37							34	33	36	36	35	36						
Adj. Stability	34	33	39	36	35	35							36	35	37	37	36	37						
Compress Str. (psi)							3450	3470	3020	2920									3690	3690	2840	2890		
IRS %							88	84											77	78				
MR1 (ksi)											430	411											434	456
MR2 (ksi)											314	416											327	407
IRMR %											73	101											75	89

Project: Temp-Vis Research
Mix #: 94-17
Mix Date: 3/10/94
Aggregate: Riverbend
Asphalt: Chev. PBA-3

Mix #: 94-28
Mix Date: 3/15/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	282	283	277	275	275	280	280	275	275	280	275	275	315	315	316	315	315		315	315	315	315	315	315
Comp Temp (°F)	260	255	255	255	255	255	255	255	255	255	255	255	296	296	296	296	296		296	296	296	296	296	296
Asphalt %	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3
Film Thick	th	th	th	th	th	th	th	th	th	th	th	th	suff-th	suff-th	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0	0	0	0	1	1+					0	0+	0	0	0+	1+	0+	1+					0	
Height (in.)	2.60	2.60	2.58	2.58	2.56	2.57	4.09	4.06	4.08	4.06	2.57	2.60	2.60	2.60	2.63	2.55	2.56	2.52	4.11	4.12	4.11	4.09	2.53	2.59
Specific Grav.	2.320	2.298	2.332	2.321	2.348	2.355	2.241	2.252	2.241	2.247			2.302	2.290	2.293	2.339	2.346	2.366	2.222	2.216	2.218	2.234		
Rice Grav.	2.482	2.482	2.457	2.457	2.445	2.445	2.457	2.457	2.457	2.457			2.469	2.469	2.457	2.457	2.444	2.444	2.457	2.457	2.457	2.457		
Air Voids %	6.5	7.4	5.1	5.5	4.0	3.7	8.8	8.3	8.8	8.5			6.8	7.2	6.7	4.8	4.0	3.2	9.6	9.8	9.7	9.1		
Stability	34	38	36	37	38	37							36	36	36	36	35	37						
Adj. Stability	36	40	37	38	39	38							38	38	38	37	36	37						
Compress Str. (psi)							2570	2940	2930	3210									3350	2900	2380	2420		
IRS %							94	92											71	83				
MR1 (ksi)											142	175											243	214
MR2 (ksi)											174	189											221	202
IRMR %											123	108											91	94

Project: Temp-Vis Research
Mix #: 94-18
Mix Date: 3/10/94
Aggregate: Coffee Lake - Reed
Asphalt: Chev. PBA-3

Mix #: 94-29
Mix Date: 3/15/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	280	275	280	275	280	295	285	275	275	279	295	293	315	315	315	315	315	315	315	315	315	315	315	315
Comp Temp (°F)	255	255	255	255	256		260	255	255	255	255	255	296	296	296	296	296	296	296	296	296	296	296	296
Asphalt %	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6
Film Thick	th	th	th-th	th-th	th-th+	th-th+	th	th	th	th	th	th	suff-th	suff-th	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0+	0+	1+	1+	2	1+					0+	0+	0+	1	1+	1+	1+	1+					1	1+
Height (in.)	2.47	2.47	2.43	2.44	2.45	2.43	3.88	3.89	3.88	3.88	2.47	2.46	2.44	2.46	2.43	2.45	2.44	2.42	3.89	3.88	3.88	3.88	2.44	2.44
Specific Grav.	2.452	2.450	2.474	2.470	2.473	2.484	2.371	2.37	2.373	2.37			2.453	2.453	2.455	2.466	2.459	2.485	2.365	2.369	2.369	2.373		
Rice Grav.	2.594	2.594	2.558	2.558	2.549	2.549	2.558	2.558	2.558	2.558			2.593	2.593	2.576	2.576	2.559	2.559	2.576	2.576	2.576	2.576		
Air Voids %	5.5	5.6	3.3	3.4	3.0	2.6	7.3	7.3	7.2	7.3			5.4	5.4	4.7	4.3	3.9	2.9	8.2	8.0	8.0	7.9		
Stability	37	35	38	36	39	38							40	36	39	38	37	35						
Adj. Stability	36	34	37	35	38	37							39	35	38	37	36	33						
Compress Str. (psi)							3080	3280	2970	2970									3250	3300	2720	2800		
IRS %									96	91									84	85				
MR1 (ksi)											151	182											167	162
MR2 (ksi)□											125	160											148	194
IRMR %											83	88											89	120

Project: Temp-Vis Research
Mix #: 94-16
Mix Date: 3/9/94
Aggregate: Riverbend
Asphalt: McCall PBA-5

Mix #: 94-27
Mix Date: 3/14/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	280	280	285	284	275	275	280	275	280	275	277	280	307	307	307	306	307	307	307	307	307	307	305	305
Comp Temp (°F)	255	255	255	255	255		255	255	258		255	255	290	290	290	290	290		290	290	290	290	290	289
Asphalt %	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3
Film Thick	suff	suff	th	th	th-th	th-th	th	th	th	th	th	th	suff	suff	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0+	0	0	0	1	0+					0+	0	0	0	0	0	1	1					0+	0+
Height (in.)	2.58	2.60	2.56	2.57	2.54	2.56	4.10	4.09	4.08	4.07	2.59	2.58	2.59	2.58	2.55	2.57	2.55	2.56	4.09	4.09	4.11	4.10	2.57	2.59
Specific Grav.	2.320	2.310	2.344	2.334	2.361	2.346	2.234	2.235	2.248	2.248			2.310	2.303	2.338	2.327	2.345	2.351	2.238	2.233	2.220	2.225		
Rice Grav.	2.478	2.478	2.460	2.460	2.446	2.446	2.460	2.460	2.460	2.460			2.481	2.481	2.460	2.460	2.451	2.451	2.460	2.460	2.460	2.460		
Air Voids %	6.4	6.8	4.7	5.1	3.5	4.1	9.2	9.1	8.6	8.6			6.9	7.2	5.0	5.4	4.3	4.1	9.0	9.2	9.8	9.6		
Stability	34	36	35	35	35	35							36	36	37	37	35	36						
Adj. Stability	35	38	36	36	36	36							38	37	38	38	36	37						
Compress Str. (psi)							2680	2680	4240	3690									3160	3470	3880	3920		
IRS %							63	78													82	89		
MR1 (ksi)											500	579											551	597
MR2 (ksi)											568	593											499	470
IRMR %											114	102											91	79

Project: Temp-Vis Research
Mix #: 94-15
Mix Date: 3/9/94
Aggregate: Coffee Lake - Reed
Asphalt: McCall PBA-5

Mix #: 94-26
Mix Date: 3/14/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	285	278	280	285	276	275	270	288	280	282	280	284	307	305	307	307	307	307	307	305	307	307	307	307
Comp Temp (°F)	255	255	255	255	255	255	255	255	255	255	255	255	290	290	290	287	290	290	290	290	290	290	290	290
Asphalt %	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6
Film Thick	suff	suff	th	th	th-th	th-th	th	th	th	th	th	th	suff-th	suff-th	th	th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	1	0+	1	2	3+	3					1+	1+	0	0	1	1	1	1+					0	0
Height (in.)	2.44	2.46	2.48	2.46	2.42	2.43	3.88	3.87	3.83	3.83	2.44	2.47	2.45	2.47	2.44	2.46	2.43	2.46	3.88	3.92	3.87	3.87	2.46	2.44
Specific Grav.	2.473	2.464	2.468	2.462	2.504	2.484	2.383	2.38	2.404	2.407			2.453	2.454	2.485	2.447	2.495	2.486	2.376	2.324	2.375	2.378		
Rice Grav.	2.599	2.599	2.579	2.579	2.560	2.560	2.579	2.579	2.579	2.579			2.596	2.596	2.575	2.575	2.563	2.563	2.575	2.575	2.575	2.575		
Air Voids %	4.8	5.2	4.3	4.5	2.2	3.0	7.6	7.7	6.8	6.7			5.5	5.5	3.5	5.0	2.7	3.0	7.7	9.7	7.8	7.7		
Stability	39	37	38	37	39	37							41	38	40	37	39	41						
Adj. Stability	38	36	38	36	37	36							40	37	39	36	38	40						
Compress Str. (psi)							3360	3620	3930	3900									4320	4300	4010	4040		
IRS %							85	93											93	94				
MR1 (ksi)											672	573											565	565
MR2 (ksi)											472	486											630	610
IRMR %											70	85											112	108

Project: Temp-Vis Research
Mix #: 94-19
Mix Date: 3/11/94
Aggregate: Riverbend
Asphalt: Chev. PBA-6

Mix #: 94-30
Mix Date: 3/16/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp (°F)	285	280	278	275	280		280	280	282	282	280	275	316	316	316	316	316	316	316	316	316	316	316	316
Comp. Temp. (°F)	255	255	255	255	255		255	255	255		255	255	301	301	301	301	301	301	301	301	301	301	301	301
Asphalt %	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3	4.8	4.8	5.3	5.3	5.8	5.8	5.3	5.3	5.3	5.3	5.3	5.3
Film Thick	suff	suff	suff-th	suff-th	th	th	th	th	th	th	th	th	th	th	th-th	th-th	th-th	th-th	th	th	th	th	th	th
Surface Cond.	0	0	0+	0+	1	1					0	0+	0+	0	0+	0+	1	1+					0+	1
Height (in.)	2.60	2.64	2.60	2.56	2.60	2.59	4.11	4.07	4.11	4.12	2.57	2.56	2.57	2.59	2.54	2.56	2.54	2.55	4.10	4.15	4.10	4.11	2.54	2.55
Specific Grav.	2.308	2.274	2.308	2.343	2.329	2.331	2.231	2.251	2.238	2.23			2.314	2.290	2.349	2.321	2.363	2.360	2.225	2.203	2.231	2.219		
Rice Grav.	2.474	2.474	2.463	2.463	2.443	2.443	2.463	2.463	2.463	2.463			2.473	2.473	2.447	2.447	2.437	2.437	2.447	2.447	2.447	2.447		
Air Voids %	6.7	8.1	6.3	4.9	4.7	4.6	9.4	8.6	9.1	9.5			6.4	7.4	4.0	5.1	3.0	3.2	9.1	10.0	8.8	9.3		
Stability	36	35	34	38	37	34							38	38	33	36	33	37						
Adj. Stability	38	37	36	39	39	36							39	40	34	37	34	38						
Compress Str. (psi)							2880	3450	3920	3950									3960	3800	3420	3380		
IRS %									74	87									86	90				
MR1 (ksi)											169	184											196	230
MR2 (ksi)											175	172											223	224
IRMR %											104	93											114	97

Project: Temp-Vis Research
Mix #: 94-20
Mix Date: 3/11/94
Aggregate: Coffee Lake - Reed
Asphalt: Chev. PBA-6

Mix #: 94-31
Mix Date: 3/16/94

	Normal Temperatures												Viscosity Temperatures											
	Stability						IRS				IRMR		Stability						IRS				IRMR	
	1	2	3	4	5	6	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	1	2
Mix Temp. (°F)	280	278	280	285	278	270	275	278	280	282	278	280	316	316	316	316	316	316	316	316	316	316	316	316
Comp. Temp. (°F)	255	255	255	255	255	255	255	255	255	255	255	255	301	301	301	301	301	301	301	301	301	301	301	301
Asphalt %	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6	5.1	5.1	5.6	5.6	6.1	6.1	5.6	5.6	5.6	5.6	5.6	5.6
Film Thick	suff	suff	th	th	th-th	th-th	th	th	th	th	th	th	suff-th	suff-th	th	th	th	th	th	th	th	th	th	th
Surface Cond.	0	1	0+	0+	1+	2					0+	1	0+	1	1	1+	2						1	
Height (in.)	2.48	2.46	2.44	2.45	2.45	2.44	3.84	3.87	3.90	3.87	2.46	2.44	2.45	2.43	2.43	2.42	2.40	2.41	3.89	3.89	3.87	3.85	2.45	2.44
Specific Grav.	2.440	2.441	2.470	2.467	2.473	2.484	2.389	2.382	2.363	2.38			2.457	2.49	2.464	2.479	2.495	2.501	2.363	2.356	2.377	2.394		
Rice Grav.	2.593	2.593	2.574	2.574	2.554	2.554	2.574	2.574	2.574	2.574			2.594	2.594	2.572	2.572	2.553	2.553	2.572	2.572	2.572	2.572		
Air Voids %	5.9	5.9	4.0	4.2	3.2	2.7	7.2	7.5	8.2	7.5			5.3	4.0	4.2	3.6	2.3	2.0	8.1	8.4	7.6	6.9		
Stability	37	38	40	38	38	39							39	36	37	39	40	41						
Adj. Stability	37	37	39	37	37	38							38	35	36	37	38	39						
Compress Str. (psi)							3620	3850	3840	3910									3590	3940	3510	3880		
IRS %									95	99									98	98				
MR1 (ksi)											172	188											172	182
MR2 (ksi)											125	162											163	205
IRMR %											73	86											95	113