EVALUATION OF THE RUTTING POTENTIAL OF KDOT MIXTURES USING THE ASPHALT PAVEMENT ANALYZER

Report Number: K-TRAN: KU-00-1

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RESEARCH

Introduction
Pavement deformation of hot mix asphalt mixtures (HMA) is one of the major distresses affecting pavement performance. With the current Superpave mix design method, there is no strength or permanent deformation testing of the HMA mixture.

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The objectives of this study were to evaluate KDOT mixtures, obtained from in-place pavements, at various test temperatures and rutting cycles in the Asphalt Pavement Analyzer (APA) and develop a test method to evaluate the rutting potential of Kansas mixtures.

Project Description
Six different pavements in Kansas with heavy truck traffic were sampled for testing and evaluation. Both 150 mm diameter core samples and laboratory compacted samples from each site were evaluated in the APA. Laboratory compacted samples were recovered from the pavement cores using an ignition furnace. The samples were tested in the APA at various test temperatures and the rut depths recorded. The APA rut depths were correlated to field rut depth measurements to assist in developing a threshold limit for HMA permanent deformation evaluation.

Project Results
The results indicate that the APA can identify the rutting susceptibility of Kansas HMA mixtures. Laboratory compacted samples proved superior to pavement cores. Threshold limits for laboratory compacted samples were established to prevent code 1 rutting (>6.35 mm) and code 2 rutting (>12.7 mm).

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FINAL REPORT

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Stephen A. Cross, P.E.

University of Kansas
Lawrence, Kansas

MAY 2004

K-TRAN

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16 Abstract

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Six different pavements in Kansas with heavy truck traffic were sampled for testing and evaluation. Both 150 mm diameter core samples and laboratory compacted samples from each site were evaluated in the APA. Laboratory compacted samples were recovered from the pavement cores using an ignition furnace. The samples were tested in the APA at various test temperatures and the rut depths recorded. The APA rut depths were correlated to field rut depth measurements to assist in developing a threshold limit for HMA permanent deformation evaluation.

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Final Report

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A Report on Research Sponsored By

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

UNIVERSITY OF KANSAS
LAWRENCE, KANSAS

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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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ABSTRACT

Permanent deformation of hot mix asphalt mixtures (HMA) is one of the major distresses affecting pavement performance. With the current Superpave mix design method, there is no strength or permanent deformation testing of the HMA mixture. The objectives of this study were to evaluate KDOT mixtures, obtained from in-place pavements, at various test temperatures and rutting cycles in the Asphalt Pavement Analyzer (APA) and develop a test method to evaluate the rutting potential of Kansas mixtures.

Six different pavements in Kansas with heavy truck traffic were sampled for testing and evaluation. Both 150mm diameter core samples and laboratory compacted samples from each site were evaluated in the APA. Laboratory compacted samples were prepared using an AC-20 asphalt cement, which met the high temperature requirements for a PG64 asphalt. The aggregates utilized to fabricate the laboratory compacted samples were recovered from the pavement cores using an ignition furnace. The samples were tested in the APA at various test temperatures and the rut depths recorded. The APA rut depths were correlated to field rut depth measurements to assist in developing a threshold limit for HMA permanent deformation evaluation.

The results indicate that the APA can identify the rutting susceptibility of Kansas HMA mixtures. Laboratory compacted samples proved superior to pavement cores. Threshold limits for laboratory compacted samples were established to prevent code 1 rutting (>6.35 mm) and code 2 rutting (>12.7 mm).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

BACKGROUND

Permanent deformation of hot mix asphalt mixtures (HMA) is one of the major distresses affecting pavement performance. With the current Superpave mix design method, there is no strength or permanent deformation testing of the HMA mixture. Therefore, much interest has developed in the use of loaded wheel testers to evaluate HMA mixtures. Cooley, et al. (1) reviewed the loaded wheel testers currently available and concluded that wheel tracking devices can be used as a pass-fail test for permanent deformation resistance if properly correlated to local traffic and environmental conditions. The Asphalt Pavement Analyzer (APA) is one of several loaded wheel testers that has shown promise for use as a mix design proof test for both permanent deformation and moisture damage. Brown, et al. (2) recommended the APA as the best currently available proof tester for evaluation of Superpave mixtures and the APA is being used successfully by several states to evaluate the permanent deformation potential of HMA mixes. A review by the New Mexico State Highway and Transportation Department of current state practice regarding APA usage and specification limits is shown in table 1. The survey indicates a wide range in test temperatures and specification limits, indicating the need for local calibration.

As recommended by Cooley, et al. (1), to successfully utilize the APA for evaluation of permanent deformation, the APA settings need to be adjusted for local conditions. The APA Users Group (3) determined that there is no agreement on either a rut depth threshold value or APA test settings and that these parameters should be

Table 1. NMSH&TD Summary of APA Strength Test Practices in Different States

State	PG High Temp. degrees C/F	Cycles	Air Voids %	Hose Pressure psi	Rutting at 100 lbs. Load Failure	No. of Gyra-tions	Remarks	Contact Person	E-Mail Address
Alabama	67/153	8000	4	100	greater than 4.5 mm			Larry Locket	Lockettl@dot.state.al.us
Arkansas	64/147	8000		100	8.0 mm	115		Jim W. Gee	Jim.Gee@ahtd.state.ar.us
					5.0 mm	160			
					3.0 mm	205			
Florida	64/147	8000			Not Available		Device is still in the development stage nationally and is used only for research at FDOT.	Gregory Sholar	Gregory.Sholar@dot.state.fl.us Phone: (353) 337-3278
Georgia	49/120		6+/-1	100	greater than 5.0 mm			Bruce E. Campbell	Bruce.Campbell@dot.state.ga.us Phone: (404) 363-7503
Kentucky	64/147	8000			5.0 mm		All of the testing is done using Superpave Gyratory Compacted specimens at 75 mm in height.	Michael Black	Mblack@mail.kytc.state.ky.us
Missouri	64/147	8000		100	5.0 mm		Using 25 cycles to seat the specimen (6 inch gyratory produced) then 8000 cycles at 100 psi for rut determinations.	Joe Schroer	SCHOROJ1@mail.modot.state.mo.us Phone: (573) 526-4353
North Carolina	67/153	8000		100	Not Available (in process)		The most common used binder in NC is 64-22 which always grades out to be a 67-22.	Christopher Bacchi	cbacchi@dot.state.nc.us
Ohio	49/120	8000	7		5.0 mm			Lloyd Welker	Lloyd.welker@dot.state.oh.us
								Dave Powers	dpowers@dot.state.oh.us Phone: (614) 275-1387

Table 1 (Con't.). NMSH&TD Summary of APA Strength Test Practices in Different States

State	PG High Temp. degrees C/F	Cycles	Air Voids %	Hose Pressure psi	Rutting at 100 lbs. Load Failure	No. of Gyra-tions	Remarks	Contact Person	E-Mail Address
Oklahoma	64/147	8000	7+/-1	100	3 mm/30M+ ESALs 4 mm/10M+ ESALs 5 mm/ 3M+ ESALs 6 mm/0.3M+ ESALs 7 mm/0.3M- ESALs		Using 50 cycles for seating 150 mm SGC molded specimens. Still investigating mixtures with this device and expecting to set maximum rut depths according to traffic.	Kenneth Hobson	Khobson@fd9ns01.okladot.state.ok.us Khobson@odot.org Phone: (405) 522-4918
South Carolina	64/147	8000			5 mm			Merrill E. Zwanke Chad Hawkins	ZwankeME@dot.state.sc.us hawkinscw@dot.state.sc.us Phone: (803)737-6700
Tenessee	60/140	4000 8000	7+/-1	100	Not Available			Brian Eagan	began2@mail.state.tn.us
Utah	64/147	8000			5 mm			Howard J. Anderson	handerso@dot.state.ut.us Phone: (801) 965-4303
Virginia	49/120	8000	8+/-0.5	120	7 mm for PG-64 5.5 mm for PG-70 3.5 mm for PG-76			William R. Bailey	bailey_wr@vdot.state.va.us
West Virginia	60/140	8000	7+/-1		6 mm			John Zaniewski	Zaniewski@cemr.wvu.edu Phone: (304) 293-3031 x 2648

determined locally. If the APA is to be fully utilized in Kansas, there is a need to calibrate the machine for local conditions.

PROJECT OBJECTIVES

The objectives of this study were to evaluate Kansas Department of Transportation (KDOT) mixtures, obtained from in-place pavements, at various test temperatures in the APA and to develop a test method to evaluate the rutting potential of Kansas mixtures. Both core samples and laboratory compacted samples were evaluated from six pavements in Kansas. Rutting occurs in the top 100mm of a pavement (4), therefore, it was only necessary to evaluate the top two layers or mixtures from each pavement.

Laboratory compacted samples were prepared using an AC-20 asphalt cement, which met the high temperature requirements of a PG64 asphalt. The aggregates utilized were recovered from the cores, using an ignition furnace. The samples were tested in the APA at various test temperatures and the rut depths recorded. The rut depths were correlated to field rut depth measurements to assist in developing a threshold limit for permanent deformation mixture evaluation.

SCOPE

Six different pavements in Kansas with heavy truck traffic were sampled for testing and evaluation. One pavement site was selected with code 0 rutting (< 6.35mm), two pavement sites were selected with code 1 rutting (6.35mm-12.7mm), and three pavement sites were selected with code 2 rutting (12.7mm-25.4mm). The non-rutted pavement, code 0 rutting, was selected to have a minimum age of the top 100mm of the pavement of five years. The remaining projects were selected to have a maximum age of the top 100mm of the pavement of five years. Mixtures from intersections were excluded.

Chapter 2

Test Procedures and Test Results

PROJECT SELECTION

Six pavements from across Kansas were selected for sampling and testing. The sites were selected to be representative of heavy truck trafficked pavements in the state. One site was selected with code 0 rutting (< 6.35mm), two sites were selected with code 1 rutting (6.35mm-12.7mm) and three sites were selected with code 2 rutting (12.7mm-25.4mm). Sites with Code 3 rutting (>25.4mm) were not generally available for sampling as immediate remediation usually takes place. The locations of the pavements sampled, sampling date and traffic information, daily 80-kN equivalent single axle loads (ESALs) and average annual daily traffic (AADT), are shown in table 2. The recent pavement history, consisting of mixture type and year placed, was provided by KDOT for each site and is shown in table 3. For the hot recycle mixtures, labeled HRC, the KDOT mix designation the recovered aggregate met is shown in table 3 as well.

Table 2. Test Site Locations and Traffic Information

		Mile			ESALs/Day		AADT	
Site	Route	Post	Lane	Location	2001	1995	2001	1995
1	I-70	165.2	WBL	E. Hays	1263	940	6340	5135
2	I-70	152.0	EBL	W. Hays	1222	1001	5525	4695
3	I-70	115.2	WBL	K-198	1042	792	4745	3995
4	US-83	122.8	NBL	S. Oakley	287	241	785	615
5	I-70	45.4	WBL	Colby	1130	840	4385	3795
6	I-70	267.0	WBL	E. Salina	1226	989	7655	6060

Table 3. Pavement Layer History

Site	Route	Location	Layer	Mix Designation	Thickness	Year Placed
1	I-70	E. Hays	Surface	BM-1T	25 mm	1994
1	I-70	E. Hays	2nd	BM-1B	75 mm	1994
2	I-70	W. Hays	Surface	BM-1B	38 mm	1993
2	I-70	W. Hays	2nd	HRC/BM-2B	68 mm	1993
3	I-70	K-198	Surface	BM-1	25 mm	1994
3	I-70	K-198	2nd	HRC/BM-2B	100 mm	1994
4	US-83	S. Oakley	Surface	BM-1T	25 mm	1995
4	US-83	S. Oakley	2nd	BM-2C	125 mm	1995
5	I-70	Colby	Surface	BM-1T	25 mm	1997
5	I-70	Colby	2nd	HRC/BM-2C	140 mm	1997
6	I-70	E. Salina	Surface	SM-9.5T	40 mm	1995
6	I-70	E. Salina	2nd	SM-12.5B	40 mm	Before 1995

FIELD SAMPLING AND TESTING

Pavement Coring

Sufficient cores were obtained from each site to allow preparation of laboratory compacted samples from recovered aggregate for the top two layers. The cores were 150mm diameter and were obtained from both wheel paths and between the wheel paths. Two cores were obtained from each wheel path and 12 to 16 additional cores were obtained from between the wheel paths, depending on the thickness of the upper layers.

Rut Depth Measurements

Rut depth measurements were obtained at the time of coring using either a 2-meter steel straight edge or a string line. The maximum rut depth in each wheel path was measured in the immediate vicinity of coring, in accordance with the procedures recommended in the SHRP Distress Identification Manual (5). Figures 1 and 2 show the coring patterns used and table 4 contains the results from the field rut depth measurements.

Table 4. Field Rut Depth Measurements

Site	Route	Rut Depth (mm) Inner Wheel Path	Rut Depth (mm) Outer Wheel Path	Rutting Code
1	I-70	16	16	2
2	I-70	9	10	1
3	I-70	16	19	2
4	US-83	12	13	1
5	I-70	22	16	2
6	I-70	4	6	0

LABORATORY TESTING

Mixture Properties

The cores obtained from the field were returned to the University of Kansas for evaluation and testing. After the cores were air-dried, the individual layers or mixtures from each core were identified, marked on the core for sawing and the thickness of each layer determined. A minimum of two cores from each site were selected for further mixture analysis. The remaining cores were set aside for APA testing. Numerous studies (4,6,7) have shown that rutting is limited to the top 100mm of a pavement, therefore, only the top two layers or mixtures from each site were tested.

Figure 1. Coring Operation and Cores from Inner Wheel Path

Figure 2. Obtaining Cores from Between Wheel Paths

Mixture analysis consisted of determining the asphalt content, recovered aggregate gradation and maximum theoretical specific gravity of the top two layers or mixtures from each site. The cores selected for mixture analysis were sawed into their respective layers and the bulk specific gravity determined in accordance with KT-15, Procedure III. Next, the maximum theoretical specific gravity (Gmm) was determined in accordance with KT- 39. After Gmm determination, the asphalt content was determined in accordance with KT-57. A correction factor of –0.26 percent was applied to the recorded asphalt content. The gradation of the recovered aggregate was determined in accordance with KT-34. The average results are shown in table 5.

Core Samples

A minimum of six cores from between the wheel paths of each site were selected for APA testing. The top 75 ±3mm of mix were removed from each core by sawing. After sawing, the cores were labeled and allowed to air dry. Next, the bulk specific gravity (Gmb) was determined in accordance with KT-15, Procedure III. The results are shown in table 6. The voids total mix (VTM) of each sample was calculated using a combined maximum theoretical specific gravity (Gmm) from each mixture present in the 75mm core. The results are shown in table 6 as well.

After bulk specific gravity testing, APA testing commenced. APA testing was performed in accordance with the draft AASHTO Test Method prepared by the APA User Group (8). A copy of the draft test procedure is in the appendix. The APA test chamber was brought to the desired test temperature and allowed to stabilize for 24 hours prior to placing test samples in the chamber. Test samples were brought to test temperature by securing the test samples in the test molds and placing them in the

Table 5. Extracted Gradations

Sieve Size (mm)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
	Percent Retained					
Layer 1						
19.0	0.0	0.0	0.0	0.0	0.0	
12.5	0.0	7.3	0.4	0.5	0.0	0.0
9.5	5.3	17.8	3.8	10.1	10.3	5.5
4.75	43.0	48.3	23.1	47.3	46.1	43.6
2.36	60.5	62.8	40.1	62.6	62.7	58.3
1.18	73.8	73.9	54.5	74.5	74.7	69.1
0.600	81.1	82.6	67.0	81.6	81.6	77.6
0.300	87.7	88.3	79.9	87.2	88.1	84.5
0.150	92.8	91.1	90.0	91.0	92.3	89.6
0.075	95.2	92.4	94.0	93.3	94.3	91.7
AC %	5.59	5.13	6.25	5.08	5.82	4.50
Gmm	2.446	2.429	2.377	2.381	2.412	2.488
Layer 2						
19.0	0.0	0.0	0.0	0.0	1.6	0.0
12.5	7.1	13.8	6.2	11.1	26.3	9.4
9.5	18.3	28.9	15.1	24.5	41.5	25.6
4.75	45.0	56.7	30.1	53.4	60.7	51.7
2.36	64.2	68.7	43.9	64.8	71.1	65.0
1.18	73.8	76.9	58.3	74.1	78.6	75.1
0.600	82.6	84.3	69.0	82.9	83.9	82.9
0.300	88.1	89.6	80.0	90.1	89.4	88.5
0.150	93.2	92.3	90.1	93.2	93.5	91.2
0.075	95.8	93.6	94.3	95.0	95.8	92.3
AC (%)	4.89	4.81	5.37	4.47	4.57	5.19
Gmm	2.482	2.431	2.432	2.444	2.438	2.447

Table 6. APA Core Sample Voids Total Mix

Site	Core	Gmb	Composite Gmm	Composite VTM (%)
1	7	2.338	2.472	5.4
1	10	2.348	2.472	5.0
1	6	2.343	2.472	5.2
1	11	2.344	2.472	5.2
1	4	2.345	2.472	5.1
1	15	2.345	2.472	5.1
2	3	2.292	2.431	5.7
2	4	2.290	2.431	5.8
2	1	2.301	2.431	5.3
2	5	2.288	2.431	5.9
2	2	2.288	2.431	5.9
2	6	2.269	2.431	6.7
2	10	2.291	2.431	5.8
2	11	2.288	2.431	5.9
3	3	2.314	2.413	4.1
3	6	2.315	2.413	4.1
3	9	2.313	2.413	4.1
3	11	2.310	2.413	4.3
3	8	2.315	2.413	4.1
3	12	2.316	2.413	4.0

Table 6 (Con't.). APA Core Sample Voids Total Mix

Site	Core	Gmb	Composite Gmm	Composite VTM (%)
4	8	2.297	2.444	6.0
4	9	2.300	2.444	5.9
4	7	2.299	2.444	5.9
4	12	2.292	2.444	6.2
4	2	2.306	2.444	5.6
4	10	2.304	2.444	5.7
4	1	2.303	2.444	5.8
4	14	2.311	2.444	5.4
5	2	2.369	2.429	2.5
5	9	2.369	2.429	2.5
5	3	2.368	2.429	2.5
5	12	2.382	2.429	1.9
5	5	2.373	2.429	2.3
5	6	2.381	2.429	2.0
6	3	2.341	2.468	5.1
6	5	2.326	2.468	5.8
6	6	2.328	2.468	5.7
6	10A	2.329	2.468	5.6
6	9	2.337	2.468	5.3
6	20	2.364	2.468	4.2
6	4	2.340	2.468	5.2
6	21	2.363	2.468	4.3

preheated APA test chamber for six hours. After the samples stabilized to the test temperature, APA testing commenced. Samples were tested to 8,000 load cycles by passing a 0.44 kN loaded wheel over a rubber hose, pressurized to 690 kN/m^2, that rests on top of the samples. Replicate samples from each site were tested at 58^{o}C, 64^{o}C and 70^{o}C. Rut depths were recorded manually at 0, 500, 1000, 2000, 4000 and 8000 load cycles. The results are shown in table 7.

Table 7. APA Rut Depth Measurements from Core Samples

Site	Core	Gmb	Composite Gmm	Composite VTM (%)	Test Temp (C)	Max Rut Depth (mm)
1	7	2.338	2.472	5.4	58	4.22
1	10	2.348	2.472	5.0	58	
1	6	2.343	2.472	5.2	64	5.62
1	11	2.344	2.472	5.2	64	
1	4	2.345	2.472	5.1	70	6.52
1	15	2.345	2.472	5.1	70	
2	3	2.292	2.431	5.7	58	5.86
2	4	2.29	2.431	5.8	58	
2	1	2.301	2.431	5.3	64	7.11
2	5	2.288	2.431	5.9	64	
2	2	2.288	2.431	5.9	70	7.44
2	6	2.269	2.431	6.7	70	
2	10	2.291	2.431	5.8	76	9.15
2	11	2.288	2.431	5.9	76	
3	3	2.314	2.413	4.1	58	3.73
3	6	2.315	2.413	4.1	58	
3	9	2.313	2.413	4.1	64	8.87
3	11	2.31	2.413	4.3	64	
3	8	2.315	2.413	4.1	70	10.54
3	12	2.316	2.413	4.0	70	
4	8	2.297	2.444	6.0	58	2.62
4	9	2.300	2.444	5.9	58	
4	7	2.299	2.444	5.9	64	4.46
4	12	2.292	2.444	6.2	64	
4	2	2.306	2.444	5.6	70	4.07
4	10	2.304	2.444	5.7	70	
4	1	2.303	2.444	5.8	76	7.03
4	14	2.311	2.444	5.4	76	

Table 7 (Con't). APA Rut Depth Measurements from Core Samples

Site	Core	Gmb	Composite Gmm	Composite VTM (%)	Test Temp (C)	Max Rut Depth (mm)
5	2	2.369	2.429	2.5	58	5.13
5	9	2.369	2.429	2.5	58	
5	3	2.368	2.429	2.5	64	10.06
5	12	2.382	2.429	1.9	64	
5	5	2.373	2.429	2.3	70	11.60
5	6	2.381	2.429	2.0	70	
6	3	2.341	2.468	5.1	58	5.44
6	5	2.326	2.468	5.8	58	
6	6	2.328	2.468	5.7	64	6.18
6	10A	2.329	2.468	5.6	64	
6	9	2.337	2.468	5.3	70	6.22
6	20	2.364	2.468	4.2	70	
6	4	2.34	2.468	5.2	76	7.35
6	21	2.363	2.468	4.3	76	

Two cores each from sites 2, 4 and 6 were tested at 76°C. During the testing of these cores, the APA was upgraded allowing automatic rut depth measurement. However, the automatic rut depth measurement system did not function properly at temperatures much above 70°C. Therefore, testing at 76°C was discontinued. All rut depth measurements on core samples were made manually, even after the automatic system was available.

Laboratory Compacted Samples

The remainder of the field cores obtained from each site were utilized for making laboratory compacted samples for APA testing. First, the cores were sawed into their respective layers and the bulk specific gravity was obtained on a majority of the samples in accordance with KT-15, Procedure III. Bulk specific gravity was not determined for each layer of each core, as this information was not necessary. After bulk specific gravity determination, the cores were placed in the ignition furnace to determine the asphalt content and recover the aggregate from each layer. The asphalt content used for the laboratory compacted samples for each for each mix was determined from the average asphalt content of each layer, after applying the -0.26 percent correction factor. The results are shown in table 8. The aggregates recovered from the ignition furnace were separated by site and mix and then sieved over the 25.4-mm through the 0.600-mm sieve, inclusive. The aggregates were stored in bins, by mix, until fabrication and APA testing.

Batch weights for laboratory compacted APA samples were determined to provide a compacted sample with a height of 75 ±3mm at 7 ±0.5% VTM, at the design asphalt content. The samples were compacted using a Superpave gyratory compactor in accordance with KT-58. The samples were short-term oven-aged for two hours at the compaction temperature prior to compaction.

All samples were compacted using the same asphalt cement, a Total AC-20. The PG high temperature grade of the asphalt was PG64, determined by KDOT, in accordance with AASHTO TP 5. The test results are shown in figure 3. The specific gravity of the asphalt cement was reported as 1.0195.

After compaction, the samples were allowed to cool to room temperature and the bulk specific gravity was determined in accordance with KT-15, Procedure III. Those samples found to have a sample height within 75 ±3mm and VTM of 7±0.5% were placed into test. Two samples from each mix were tested at 52^{o}C, 58^{o}C and 64^{o}C in the

Table 8. Physical Properties of Pavement Layers From Cores

Site	Core	Layer	Gmb	Gmm	VTM (%)	AC (%)
1	1	1	2.146	2.446	12.3	5.62
1	2	1	*	2.446	*	5.54
1	3	1	2.381	2.446	2.7	5.60
1	4	1	2.193	2.446	10.4	5.46
1	5	1	2.385	2.446	2.5	*
1	8	1	2.369	2.446	3.2	5.63
1	9	1	2.368	2.446	3.2	5.62
1	12	1	2.367	2.446	3.2	*
1	13	1	2.376	2.446	2.9	5.63
1	16	1	2.376	2.446	2.9	5.60
1	17	1	2.215	2.446	9.4	*
1	Averages	1	2.318	2.446	5.3	5.59
1	1	2	2.267	2.482	8.7	4.67
1	2	2	2.259	2.482	9.0	4.75
1	3	2	2.311	2.482	6.9	4.99
1	4	2	2.256	2.482	9.1	4.94
1	5	2	2.299	2.482	7.4	4.88
1	6	2	*	*	*	4.87
1	7	2	*	*	*	5.02
1	9	2	2.308	2.482	7.0	4.82
1	10	2	*	*	*	4.75
1	11	2	*	*	*	4.98
1	13	2	2.298	2.482	7.4	4.94
1	15	2	*	*	*	5.08
1	17	2	2.303	2.482	7.2	*
1	Averages	2	2.288	2.482	7.8	4.89
2	3	1	2.307	2.429	5.0	5.13
2	4	1	2.311	2.429	4.9	5.10
2	7	1	2.300	2.429	5.3	5.25
2	8	1	2.295	2.429	5.5	5.00
2	12	1	2.287	2.429	5.8	4.97
2	13	1	2.304	2.429	5.1	5.35
2	Averages	1	2.301	2.429	5.3	5.13
2	3	2	2.306	2.431	5.2	4.32
2	4	2	2.302	2.431	5.3	*
2	6	2	*	2.431	*	4.86
2	7	2	2.296	2.431	5.5	5.16
2	8	2	2.283	2.431	6.1	*
2	9	2	2.278	2.431	6.3	4.92
2	12	2	2.270	2.431	6.6	4.82
2	13	2	2.295	2.431	5.6	4.90
2	14	2	2.253	2.431	7.3	4.71
2	Averages	2	2.285	2.431	6.0	4.81

* Test property not recorded

Table 8 (Cont.). Physical Properties of Pavement Layers From Cores

Site	Core	Layer	Gmb	Gmm	VTM (%)	AC (%)
3	1	1	*	2.377	*	6.32
3	2	1	2.240	2.377	5.7	6.27
3	3	1	*	2.377	*	6.18
3	4	1	2.259	2.377	5.0	6.19
3	5	1	2.259	2.377	5.0	6.37
3	6	1	*	2.377	*	6.29
3	7	1	2.267	2.377	4.6	6.18
3	8	1	*	2.377	*	6.34
3	9	1	*	2.377	*	6.27
3	10	1	2.207	2.377	7.1	6.26
3	11	1	*	*	*	6.25
3	12	1	2.266	2.377	4.7	6.10
3	Averages	1	2.249	2.377	5.3	6.25
3	2	2	2.395	2.432	1.5	5.34
3	4	2	2.383	2.432	2.0	5.27
3	5	2	2.385	2.432	1.9	5.45
3	7	2	2.390	2.432	1.7	5.41
3	10	2	2.397	2.432	1.4	5.51
3	12	2	2.392	2.432	1.6	5.22
3	Averages	2	2.390	2.432	1.7	5.37
4	3	1	2.239	2.381	6.0	5.05
4	4	1	2.257	2.381	5.2	4.47
4	5	1	2.256	2.381	5.3	5.31
4	6	1	2.258	2.381	5.2	5.12
4	8	1	2.269	2.381	4.7	5.30
4	9	1	2.284	2.381	4.1	5.21
4	11	1	2.239	2.381	6.0	*
4	13	1	2.260	2.381	5.1	5.13
4	Averages	1	2.258	2.381	5.2	5.08
4	3	2	2.318	2.444	5.1	4.49
4	4	2	2.312	2.444	5.4	4.42
4	5	2	2.319	2.444	5.1	4.51
4	6	2	2.313	2.444	5.3	4.53
4	8	2	2.325	2.444	4.9	4.46
4	9	2	2.321	2.444	5.0	4.46
4	11	2	2.307	2.444	5.6	4.34
4	13	2	2.318	2.444	5.1	4.51
4	Averages	2	2.317	2.444	5.2	4.47

* Test property not recorded

Table 8 (Cont.). Physical Properties of Pavement Layers From Cores

Site	Core	Layer	Gmb	Gmm	VTM (%)	AC (%)
5	4	1	too thin	2.412	too thin	5.83
5	5	1	too thin	2.412	too thin	5.83
5	8	1	too thin	2.412	too thin	5.86
5	10	1	too thin	2.412	too thin	5.86
5	13	1	too thin	2.412	too thin	5.86
5	15	1	too thin	2.412	too thin	5.86
5	16	1	too thin	2.412	too thin	5.73
5	17	1	too thin	2.412	too thin	5.73
5	Averages	1		2.412		5.82
5	2	2	*	2.438	*	4.56
5	3	2	*	2.438	*	4.66
5	5	2	*	2.438	*	4.70
5	6	2	*	2.438	*	4.42
5	8	2	2.388	2.438	2.0	*
5	9	2	*	2.438	*	4.77
5	10	2	2.390	2.438	1.9	4.51
5	13	2	2.387	2.438	2.1	4.30
5	15	2	2.391	2.438	1.9	4.65
5	16	2	2.390	2.438	2.0	4.55
5	17	2	2.395	2.438	1.7	*
5	Averages	2	2.390	2.438	1.9	4.57
6	4	1	2.311	2.488	7.1	*
6	5	1	2.340	2.488	5.9	4.32
6	6	1	2.304	2.488	7.4	4.63
6	7	1	2.294	2.488	7.8	4.52
6	8	1	2.307	2.488	7.3	4.47
6	9	1	2.320	2.488	6.8	*
6	20	1	2.333	2.488	6.2	4.61
6	21	1	2.337	2.488	6.1	*
6	10A	1	2.294	2.488	7.8	*
6	6A	1	2.344	2.488	5.8	4.13
6	1	1	2.320	2.488	6.8	4.83
6	2	1	*	2.488	*	4.45
6	Averages	1	2.319	2.488	6.8	4.50
6	5	2	2.307	2.447	5.7	5.10
6	6A	2	2.306	2.447	5.8	5.11
6	7	2	2.320	2.447	5.2	5.18
6	8	2	2.329	2.447	4.8	5.27
6	9	2	2.330	2.447	4.8	5.29
6	20	2	2.319	2.447	5.2	5.18
6	Averages	2	2.319	2.447	5.3	5.19

* Test property not recorded

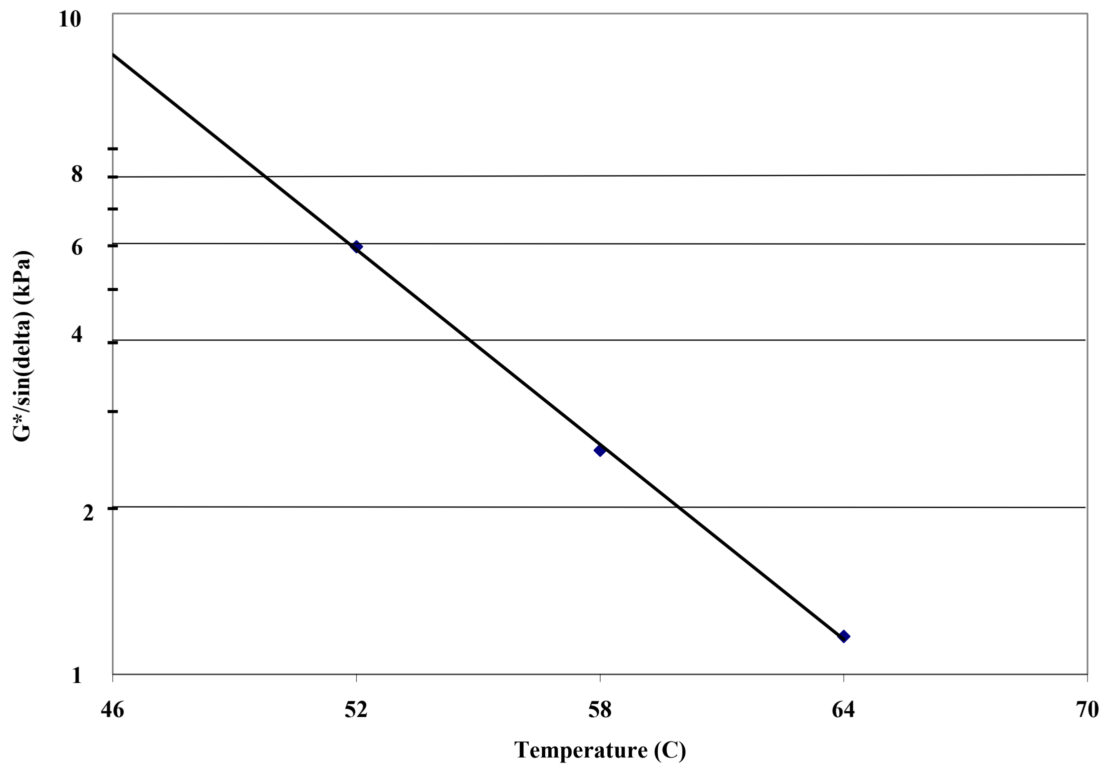

Figure 3. Results of AASHTO TP 5

APA, for a total of six samples per mix. The APA testing was performed in accordance with the draft AASHTO Test Method (8), prepared by the APA User Group, as previously described. Rut depth measurements were recorded using the automated feature of the APA. The results are shown in table 9.

Table 9. APA Rut Depth Results, Laboratory Compacted Samples

			Test Temperature			Field
			52 C	58 C	64 C	Rut Depth
Site	Route	Layer	APA Rut Depth (mm)			(mm)
1	I-70	1	6.40	7.80	9.24	16
2	I-70	1	4.97	5.75	7.46	9
3	I-70	1	10.46	11.42	13.53	19
4	US-83	1	4.94	5.99	7.13	13
5	I-70	1	*	8.56	*	22
6	I-70	1	5.04	5.96	6.42	6
1	I-70	2	3.89	4.38	6.19	16
2	I-70	2	3.82	4.68	6.01	9
3	I-70	2	7.49	11.14	13.73	19
4	US-83	2	4.09	4.77	8.77	13
5	I-70	2	7.16	9.39	11.26	22
6	I-70	2	3.37	6.69	7.56	6

* Insufficient material

Chapter 3

Analysis of Test Results

CORE SAMPLES

Rut Depth Analysis

A minimum of six cores from each site were selected and the top 75 ±3mm of mix were removed from each core by sawing for APA testing. Two cores each from each site were tested at 58°C, 64°C and 70°C. The results were shown in table 6.

Figures 4, 5 and 6 show the comparison of the field rut depths to the APA rut depths determined at 58°C, 64°C and 70°C, respectively. The relationships are poor, with R^2 values of 0.08, 0.42 and 0.51, respectively. The relationship shown in figure 4 indicates no correlation between APA and field rut depths at 58°C. In fact, the slope of the regression line is opposite of the anticipated trend. It appears that 58°C is too low of a test temperature to evaluate aged cores obtained from the roadway for permanent deformation. Figures 5 and 6 indicate a slightly better fit as the test temperature is increased, as indicated by increasing R^2 values. The average VTM of the cores varied from a low 2.3% to a high of 5.9%. VTM has been shown to have a significant effect on APA rut depths (3) and this range in VTM could account for some of the poor correlation between field and APA rut depths.

Only three sites, sites 2, 4 and 6, were tested at 76°C. Rut depths at 76°C were approximated for sites 1, 3 and 5 by plotting the rut depths at 58°C, 64°C and 70°C for each site and extrapolating the rut depth at 76°C. Using the extrapolated rut depths for sites 1, 3 and 5, the relationship between field rut depth and APA rut depth at 76°C was

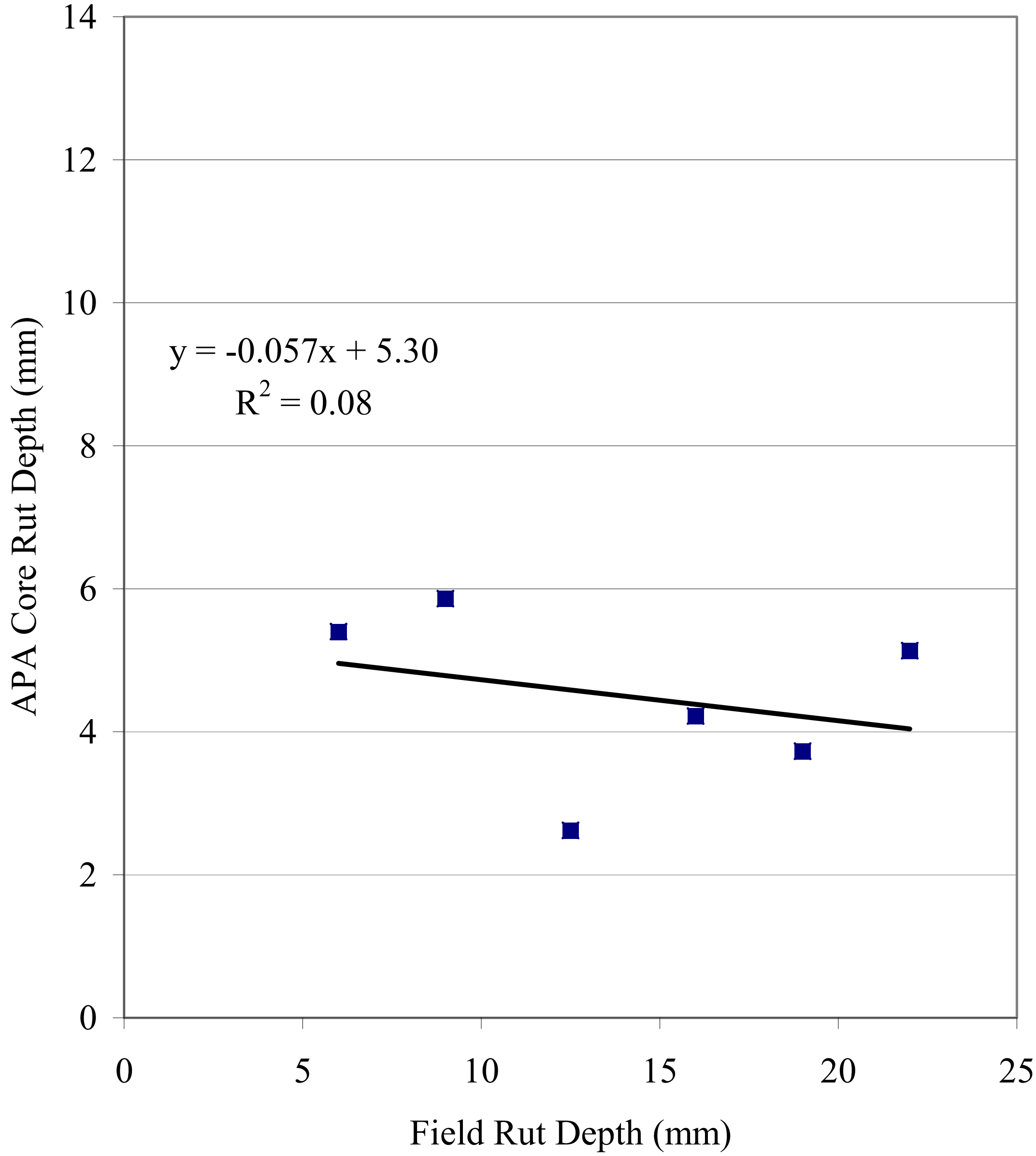

Figure 4. Field Rut Depth vs. Core APA Rut Depth at 58°C

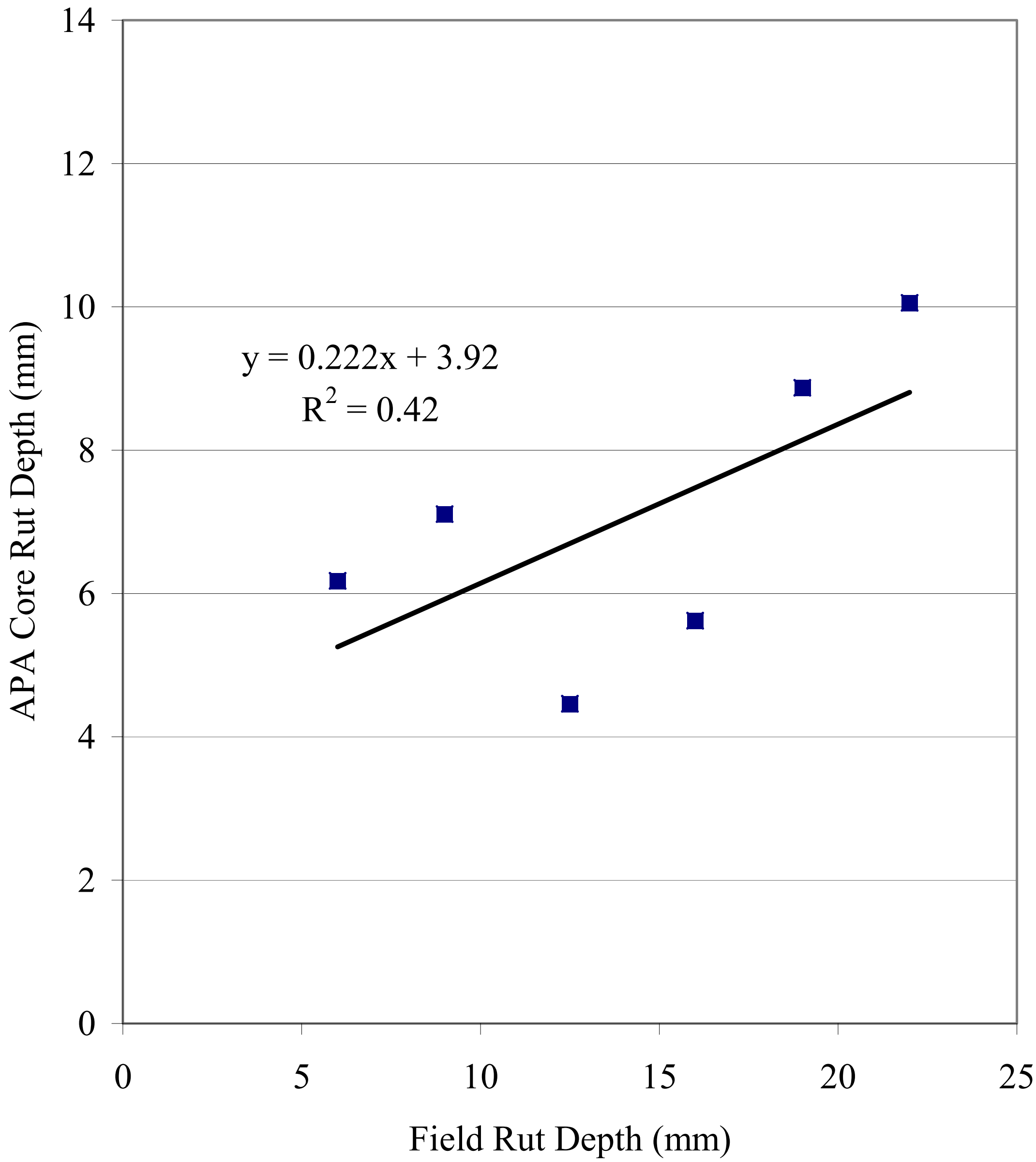

Figure 5. Field Rut Depth vs. Core APA Rut Depth at 64^{o}C

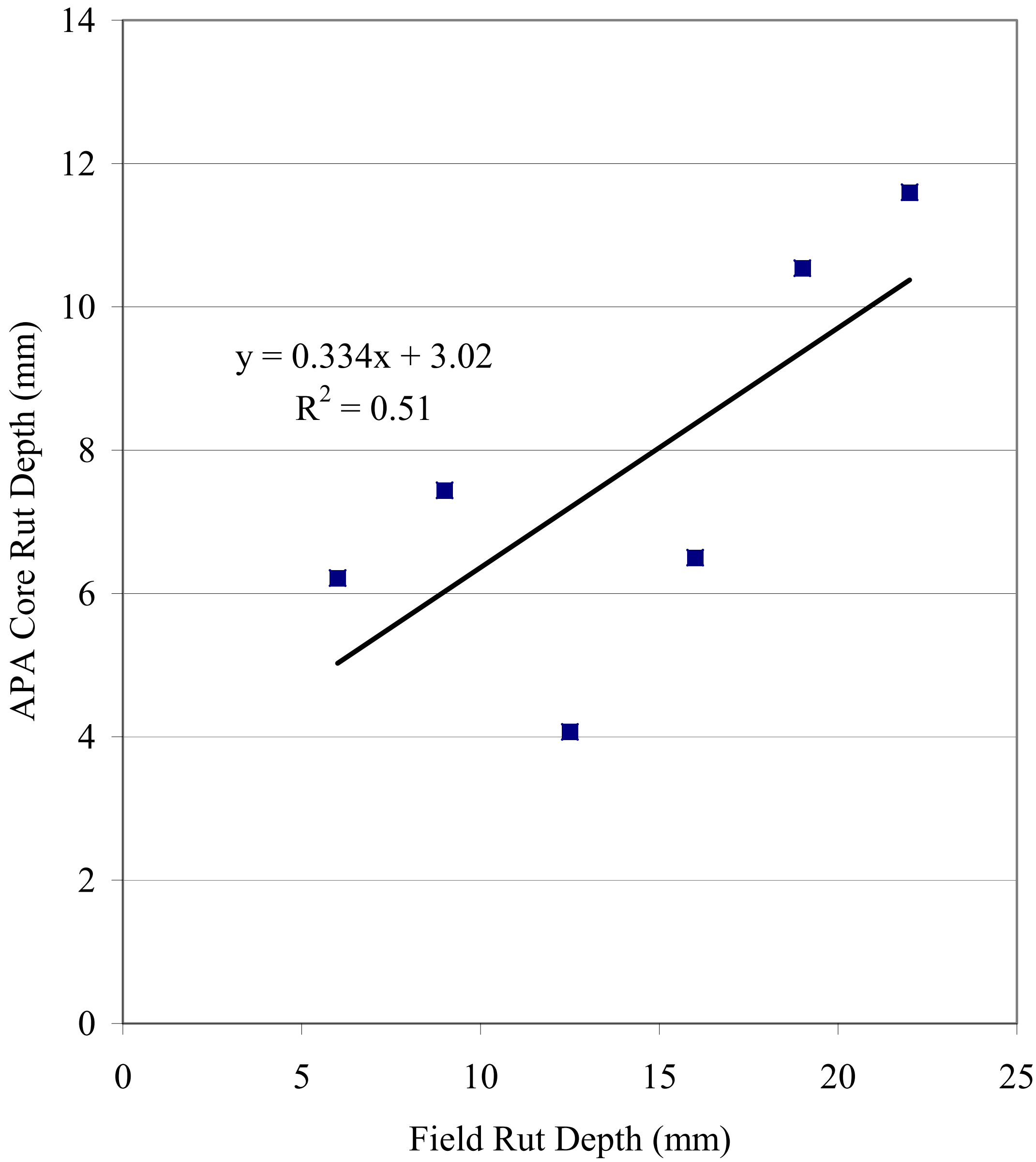

Figure 6. Field Rut Depth vs. Core APA Rut Depth at 70°C

estimated and is shown in figure 7. The fit at 76°C is slightly better than at the other test temperatures ($R^2 = 0.60$), indicating the need for higher test temperatures if aged field cores are to be used for permanent deformation evaluation. However, as can be readily seen from figure 7, the relationship is highly dependent on the extrapolated test data.

Threshold Analysis

Table 10 shows the APA threshold rut depths required to keep field rut depths below code 1 and code 2 rutting. This corresponds to a field rut depth of less than 6.35mm and 12.7mm, respectively. The threshold values were determined from the regression equations developed at each test temperature, as shown in figures 4-7. The threshold values range from 5.1mm to 6.7mm to prevent code 1 rutting (>6.35mm) and from 6.7mm to 9.1mm to prevent code 2 rutting (>12.7mm). It is interesting to note that the threshold value to prevent code 1 rutting at 70°C is lower than at 64°C. This inconsistency indicates the inadequacy of using aged cores to evaluate rutting potential of HMA mixtures. This should not be seen as a detriment to using the APA to evaluate rutting potential of HMA mixtures. The idea behind the APA is to prevent rutting by screening laboratory mixtures, not evaluating aged, in-service mixtures.

Table 10. APA Threshold Limits
for Pavement Core Samples

Threshold Limit		Test Temperature			
		58 C	64 C	70 C	76 C[1]
< Code 1	6.35 mm	*	5.33 mm	5.14 mm	6.65 mm
< Code 2	12.7 mm	*	6.74 mm	7.20 mm	9.06 mm

* No relationship found

[1] Includes extrapolated data

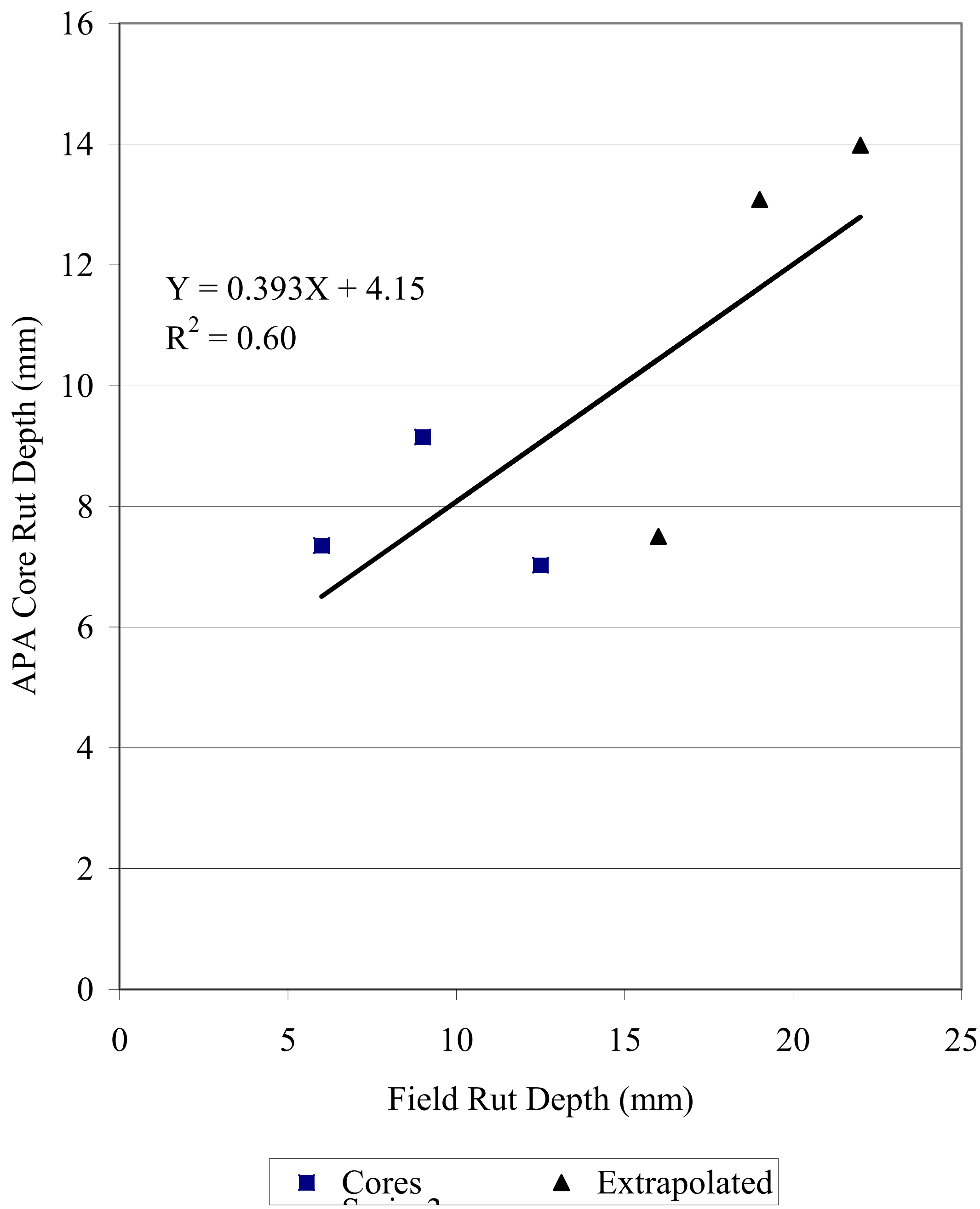

Figure 7. Field Rut Depth vs. Core APA Rut Depth at 76°C

Figures 8-11 are comparisons of the APA rut depths at 58°C, 64°C, 70°C and 76°C, respectively, sorted by rutting code. Again, figure 11 at 76°C uses extrapolated data for sites 1, 3 and 5. The threshold values to prevent code 1 and code 2 rutting are shown on figures 9-11. The results shown in figure 8 clearly indicate that 58°C is too low a test temperature for permanent deformation evaluation of in-service pavement core samples in Kansas. The remaining figures show that the code 2 threshold value correctly identifies two of the three sites with code 2 rutting. All of the sites had APA rut depths greater than the code 1 threshold value. Figures 8-11 indicate the difficulty in using aged pavement cores to evaluate rutting potential of HMA mixtures.

LABORATORY COMPACTED SAMPLES

Rut Depth Analysis

The remainder of the field cores obtained from each site were utilized for making laboratory compacted samples for APA testing. The aggregates from the top two mixes from each site were recovered from the ignition furnace and samples from each mix were batched to the average gradation of the aggregate recovered from the ignition furnace. The samples were batched to the average asphalt content determined from the ignition furnace testing. All samples were batched using a Total AC 20 asphalt cement, which tested to a PG64, the 98 percent reliability high temperature grade in Kansas. Two samples per mix from each site were tested in the APA at 52°C, 58°C and 64°C. The rut depths were recorded automatically and the results were shown in table 9.

Numerous reports have stated that rutting is limited to the top 100mm of an HMA mix (4,6,7). In addition, shear stresses near the surface of an HMA pavement, due to the load on dual tires, approach a maximum value approximately 20-25mm below the

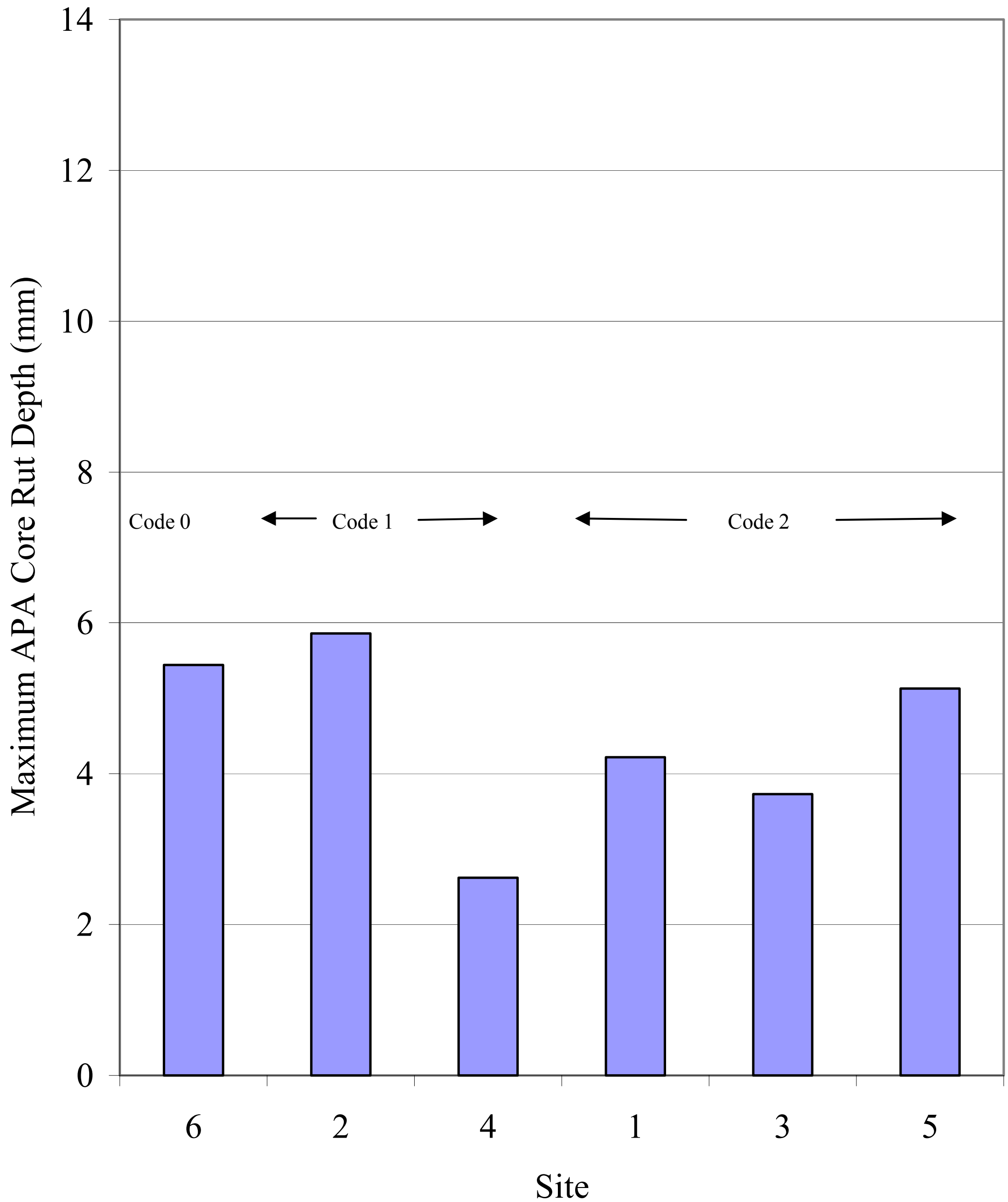

Figure 8. APA Core Rut Depths at 58^{o}C vs. KDOT Rutting Code

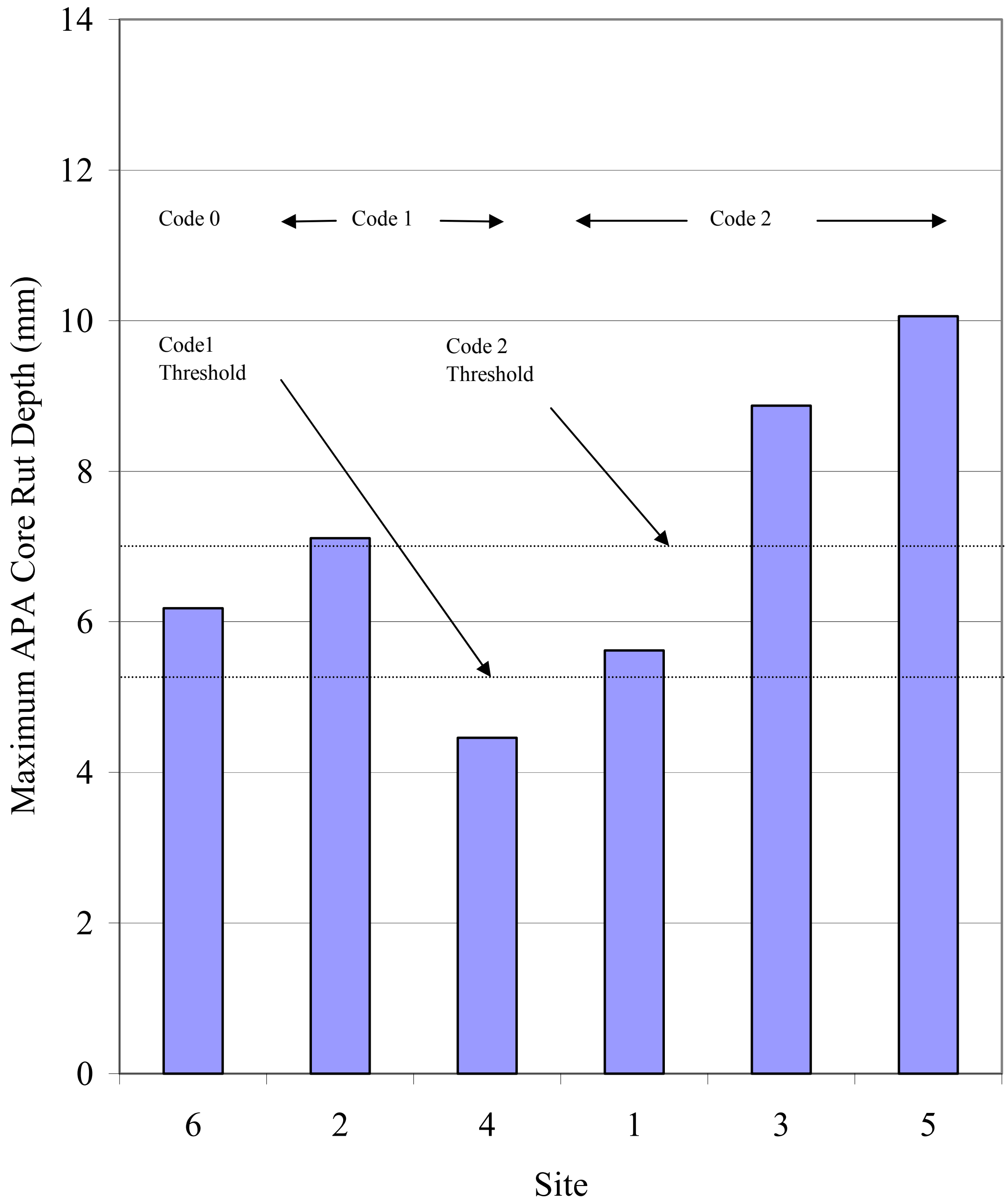

Figure 9. APA Core Rut Depths at 64^{o}C vs. KDOT Rutting Code

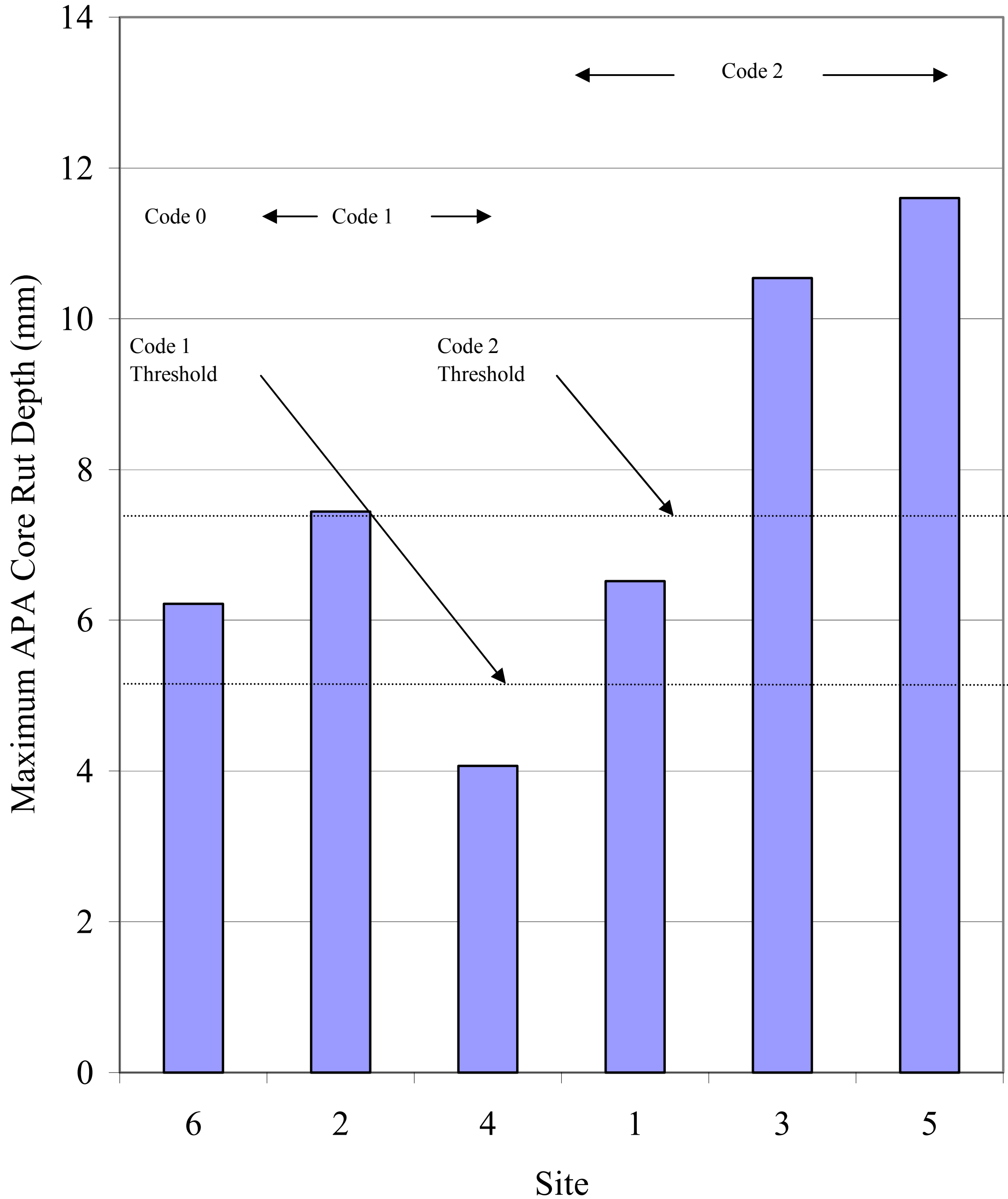

Figure 10. APA Core Rut Depths at 70°C vs. KDOT Rutting Code

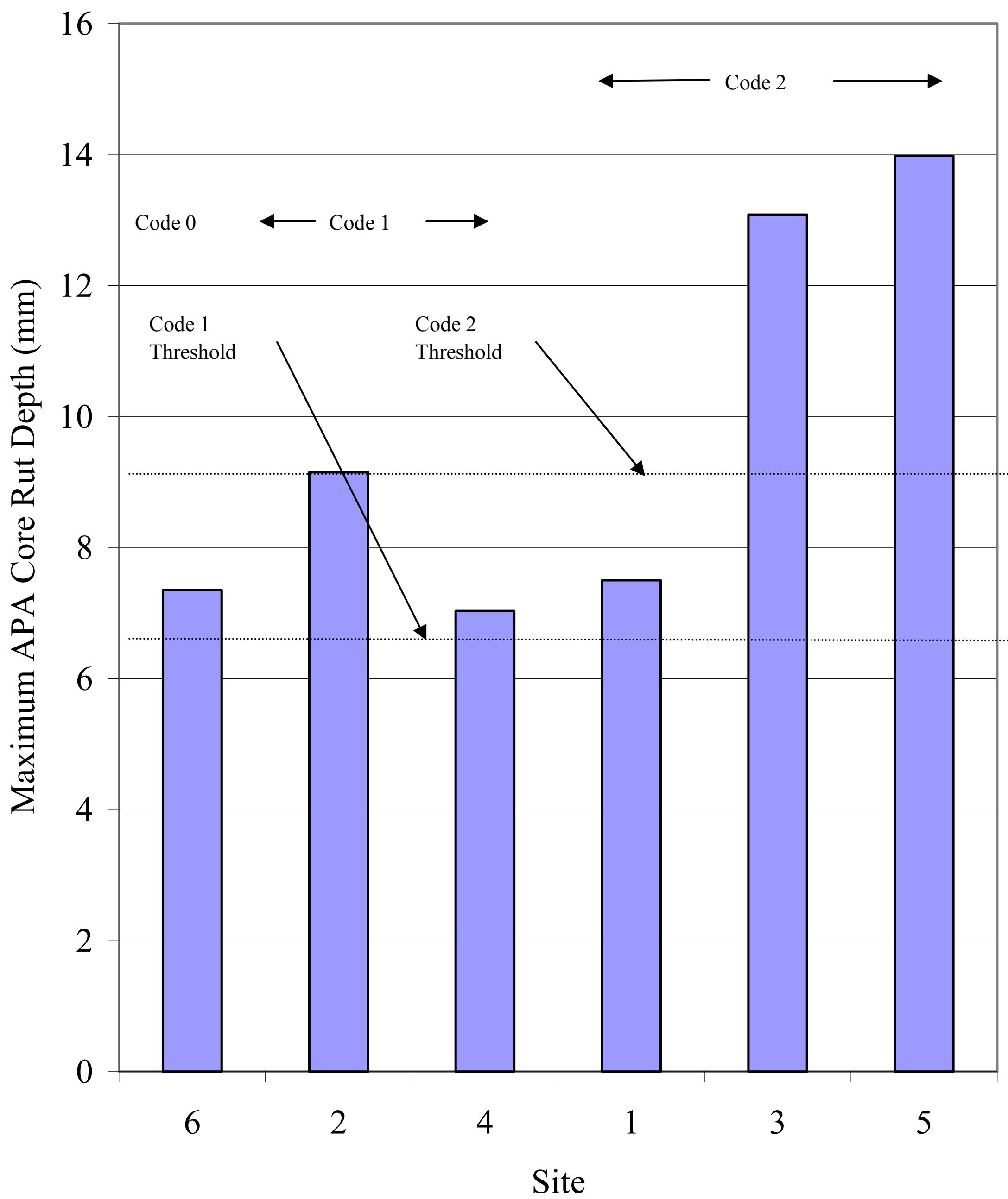

Figure 11. APA Core Rut Depths at 76°C vs. KDOT Rutting Code

pavement surface. As shown in table 3, the majority of the layer one mixes were 25mm thick, indicating that the shear stresses in the top two layers would be similar. The similar shear stresses allow the testing of the top two pavement layers in the APA under the same test conditions and allow the analysis of the layer one and layer two samples together without introducing significant error.

Figures 12, 13 and 14 show the comparison between field rut depths and APA rut depths, determined at 52°C, 58°C and 64°C, respectively. There is considerable scatter in the data, as indicated by the low R^2 values, less than 0.60. The goodness of fit (R^2) for the relationships between field rut depths and APA rut depths remain fairly constant over the test temperatures, 0.50, 0.45 and 0.57 for 52°C, 58°C and 64°C, respectively.

Several researchers have reported relationships between traffic and rut depths (4, 6, 9, 10). Therefore, the effect of traffic, as measured by ESALs and log(ESALs), on the correlation between field and APA rut depths was evaluated as well. Traffic, as measured by ESALs and log(ESALs), did not improve the relationships shown in figures 12-14.

Threshold Analysis

Table 11 shows the APA threshold rut depths required to keep field rut depths below code 1 (<6.35mm) and code 2 (<12.7mm) rutting. The threshold values were determined from the regression equations developed at each test temperature, as shown in figures 12-14. The threshold values ranged from 3.7mm to 6.1mm to prevent code 1 rutting (>6.35mm) and from 5.4mm to 8.5mm to prevent code 2 rutting (>12.7mm). The spread between the threshold values for code 1 and code 2 rutting varied from a low of 1.69mm at 52°C to a high of 2.38mm at 64°C.

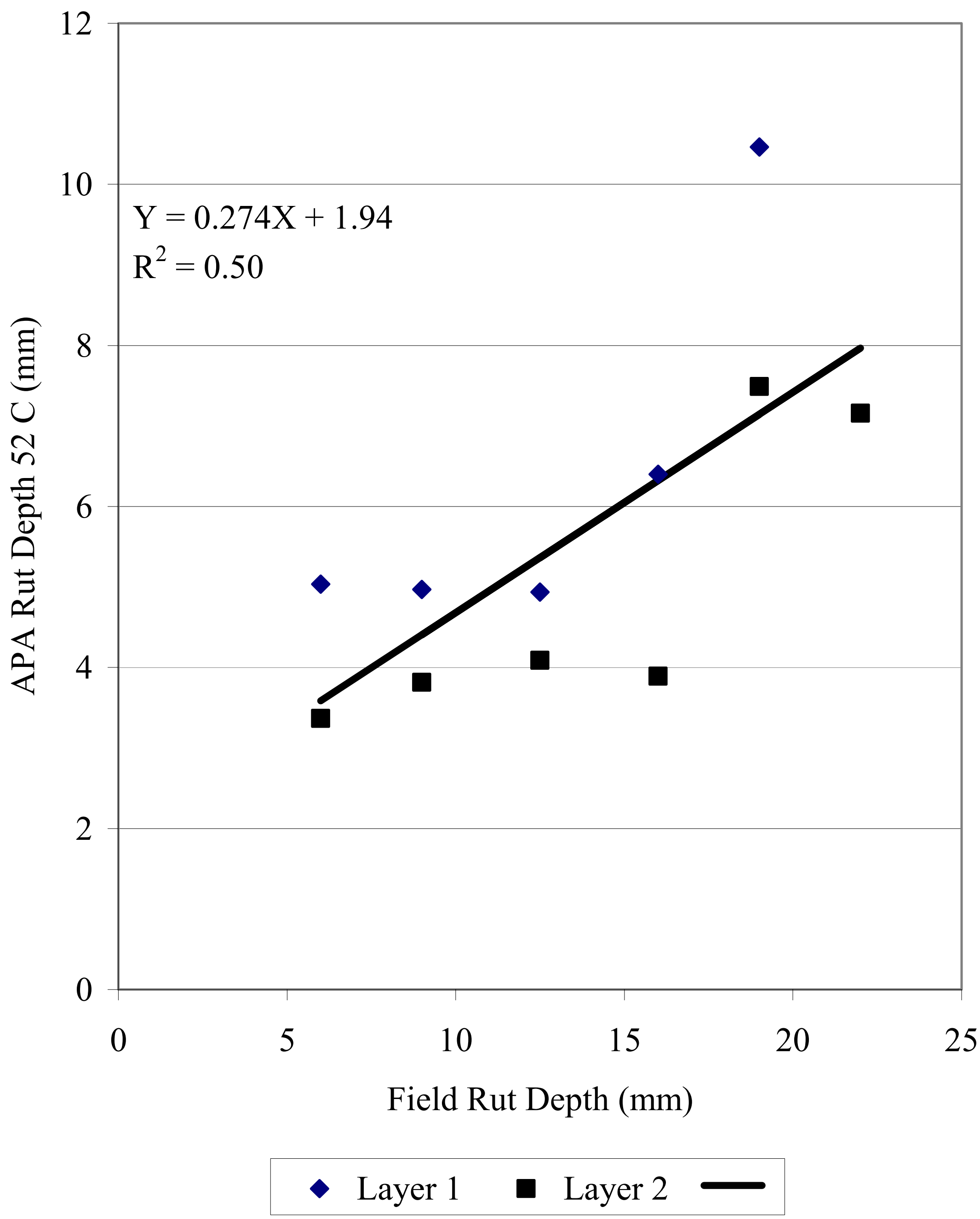

Figure 12. Field Rut Depth vs. Laboratory Compacted APA Rut Depth at 52°C

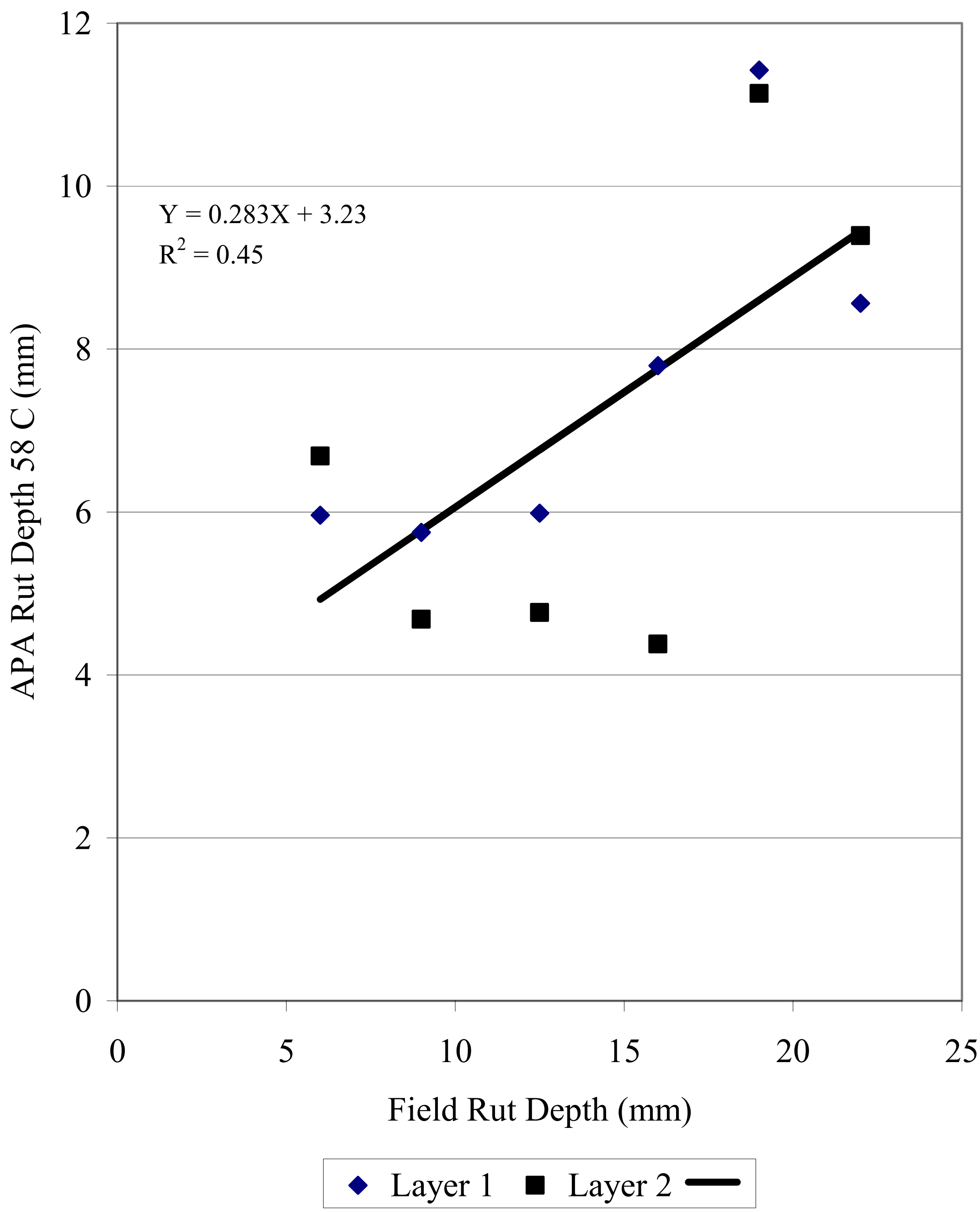

Figure 13. Field Rut Depth vs. Laboratory Compacted APA Rut Depth at 58°C

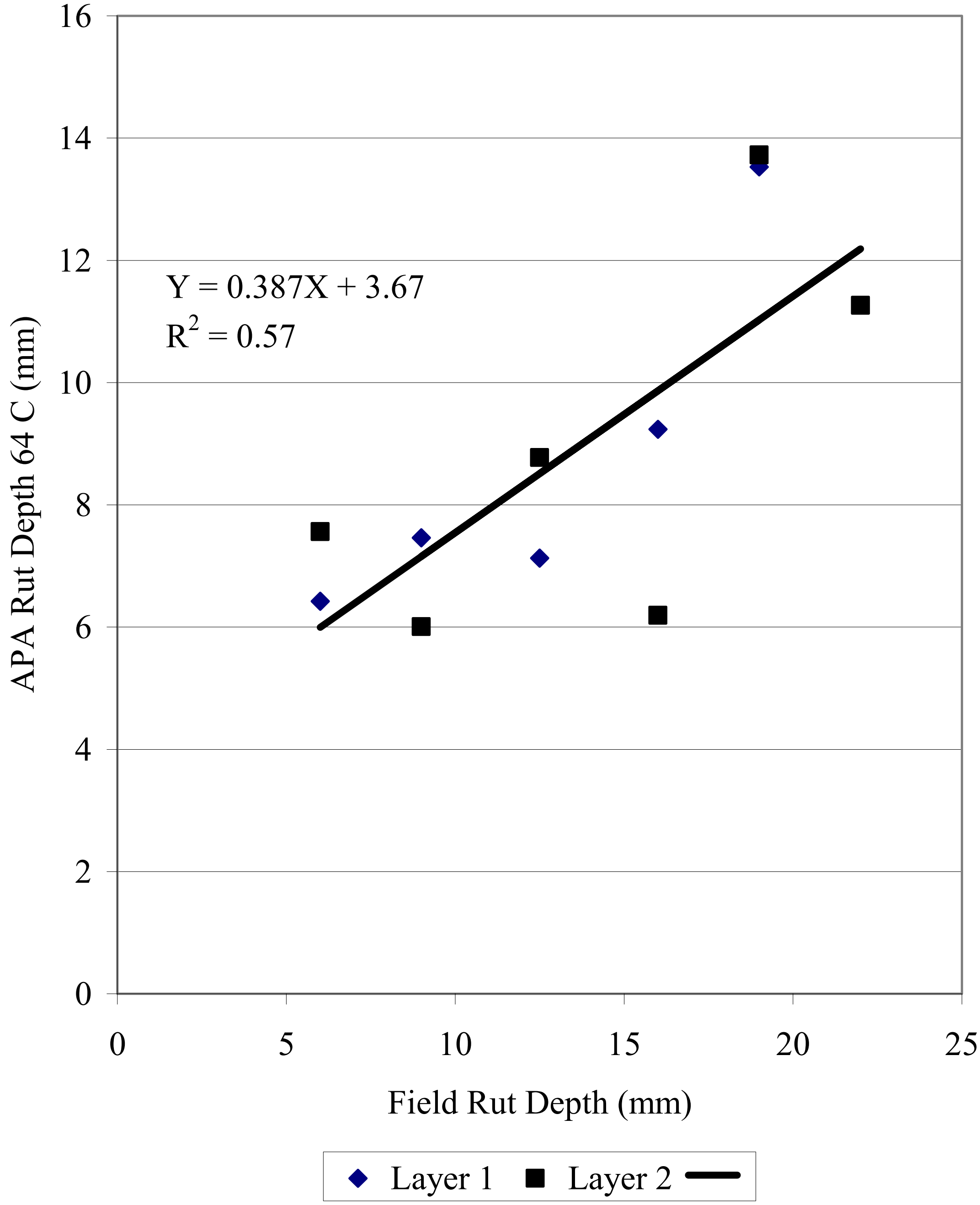

Figure 14. Field Rut Depth vs. Laboratory Compacted APA Rut Depth at 64^{o}C

Table 11. APA Threshold Limits
for Laboratory Compacted Samples

Threshold Limit		Test Temperature		
		52 C	58 C	64 C
< Code 1	6.35 mm	3.68 mm	5.03 mm	6.13 mm
< Code 2	12.7 mm	5.37 mm	6.77 mm	8.51 mm

Previous research (11) has shown that APA rut depths greater than 10-12mm are not accurate. At high rut depths, greater than 12mm, the sample mold can help support the hose. A second problem with exceedingly high APA rut depths is excessive plastic flow of the mix. Plastic flow can result in a humping up of the mix around the edge of the hose. The automated rut depth measurement system does not account for this. Therefore, it is more precise to test samples that have rut depths that fall in the middle third of the range of accuracy of the APA rut depth measuring system, 4mm to 8mm.

As seen in table 11, testing samples at 52^oC resulted in threshold limits near the lower third of what is generally considered the accurate or desirable range of rut depths in the APA. Testing at 58^oC and 64^oC results in threshold limits in the middle third of the desirable range of rut depths and should be more satisfactory for use as a specification limit.

Figures 15-17 are comparisons of APA rut depths at 52^oC, 58^oC and 64^oC, respectively, sorted by rutting code. The threshold values to prevent code 1 and code 2 rutting are shown on figures 15-17. The three figures show that the code 2 threshold value correctly identifies all three sites with code 2 rutting. Site 6 was the only site with

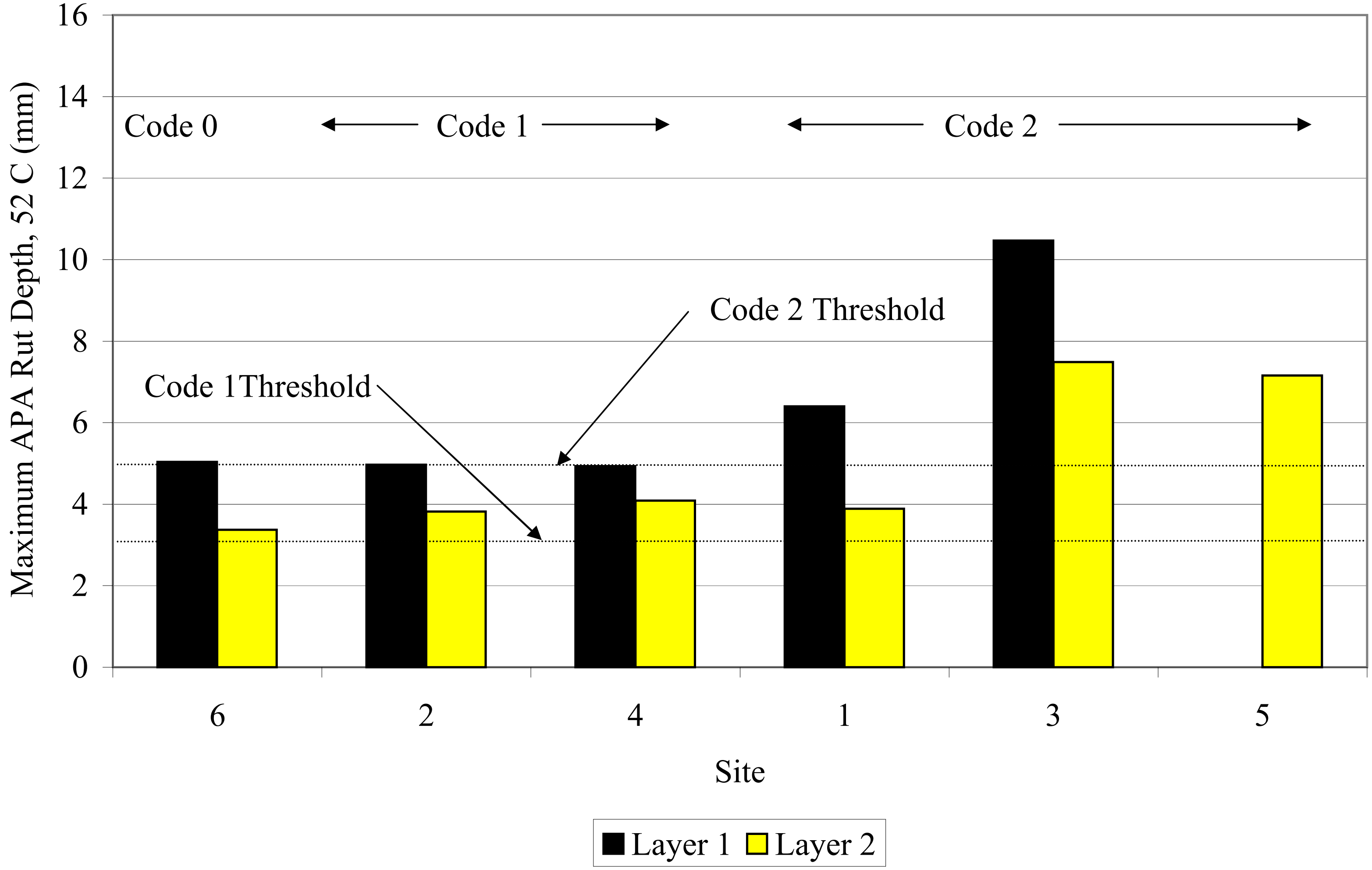

Figure 15. APA Laboratory Sample Rut Depths at 52^{o}C vs. KDOT Rutting Code

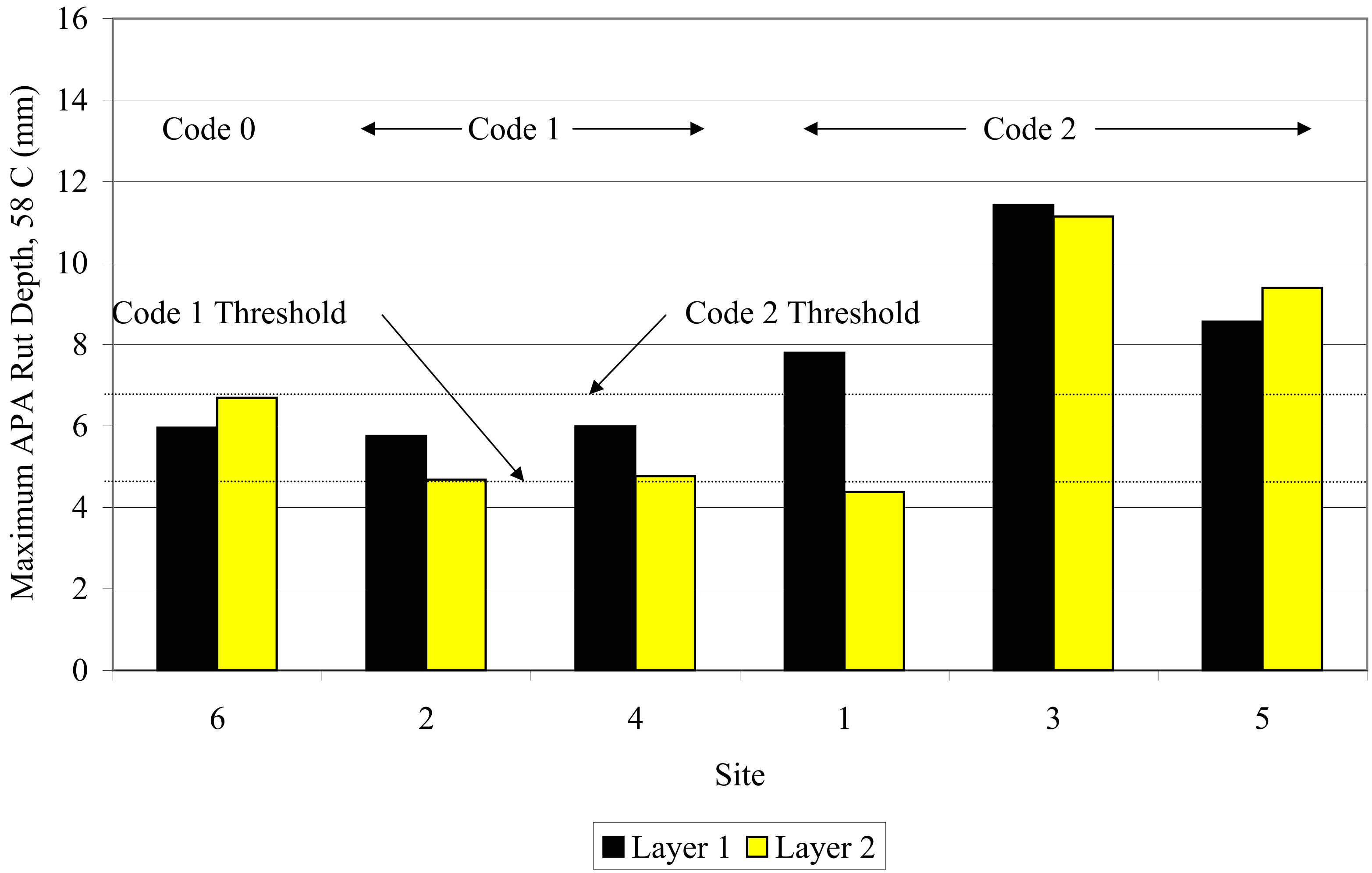

Figure 16. APA Laboratory Sample Rut Depths at 58^{o}C vs. KDOT Rutting Code

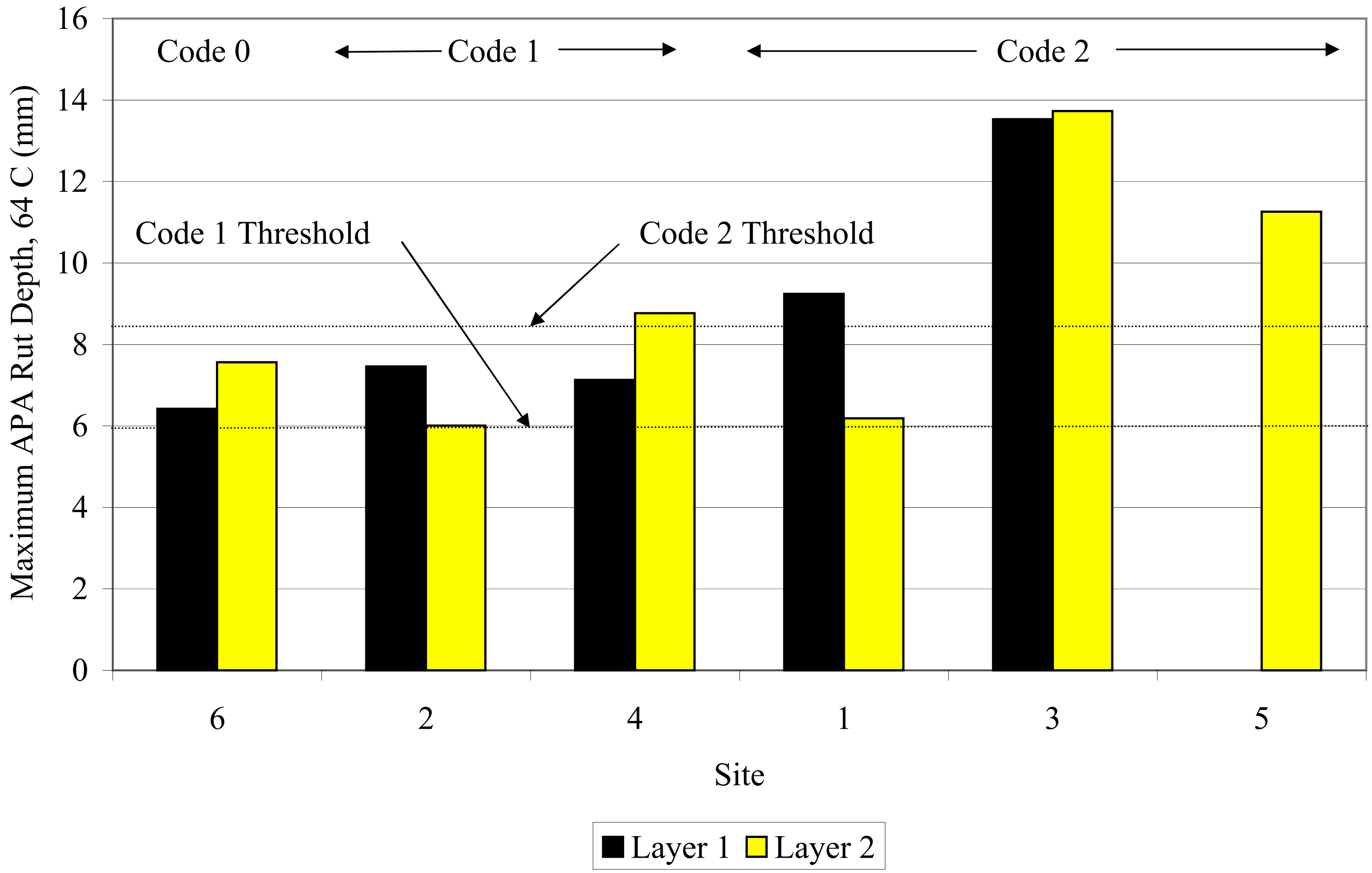

Figure 17. APA Laboratory Sample Rut Depths at 64^{o}C vs. KDOT Rutting Code

code 0 rutting; however, at all three test temperatures the site 6 mixes had APA rut depths above the code 1 threshold value. The field rut depth at site 6 was 6mm, which is just slightly below the upper limit of code 0 rutting of 6.35 mm. Secondly, all six sites were made using PG64 asphalt cement. The surface mix at Site 6 is the only Superpave mix (SM designation) evaluated and was constructed with PG70-28 asphalt cement. The use of a softer asphalt cement at the high temperature grade in the laboratory compacted samples could account for the higher APA rut depths.

Chapter 4

Conclusions, Recommendations and Implementation

CONCLUSIONS

Based on the results of this study and for the materials evaluated, the following conclusions are warranted.

1. The asphalt pavement analyzer (APA) can be used to evaluate the rutting potential of Kansas HMA mixtures, if the proper test conditions are utilized.
2. Testing the rutting potential of HMA mixtures from cores obtained from in-service pavement was not as successful as using laboratory compacted samples of the same mixture.
3. Higher APA test temperatures were required to produce similar APA rut depths for pavement cores than laboratory compacted samples.
4. An upper APA test chamber temperature for KU's APA appears to be 64^{o}C. Samples tested at 70^{o}C using the automated rut depth measurement feature occasionally malfunctioned and the automatic rut depth data was lost. It is believed this is due to a higher chamber temperature at the top of the test chamber, where the LVDTs are located, than the temperature of the test samples.
5. With KU's APA, higher test temperatures, above 64^{o}C, can be utilized with manual rut depth measurement.
6. The rutting potential of KDOT mixtures, using laboratory compacted samples, can be evaluated at test temperatures of 52^{o}C, 58^{o}C and 64^{o}C.

7. The APA rut depth threshold values to limit field rut depths to less than code 1 rutting (< 6.35mm) and less than code 2 rutting (< 12.7mm) for KDOT mixtures, traffic and environmental conditions were established and are shown below.

Test Temperature	Code 1 Threshold	Code 2 Threshold
52^{o}C	3.68 mm	5.37 mm
58^{o}C	5.03 mm	6.77 mm
64^{o}C	6.13 mm	8.51 mm

RECOMMENDATIONS

Based on the results of this study and for the materials evaluated, the following recommendations are warranted.

1. KDOT HMA mixtures should be evaluated for rutting potential using the draft APA test procedure developed by the APA User Group (8).
2. Samples made with a PG64 or lower grade asphalt cement should be tested at 58^{o}C for 8,000 cycles using a hose pressure of 690 kPa. A threshold value of 5mm should be used to prevent code 1 (> 6.35 mm) rutting. A threshold value of 7mm should be used to prevent code 2 rutting (> 12.7mm).
3. Several years of APA rutting data are available on in-service Superpave mixtures. It is recommended that field rut depth measurements be obtained from these pavements and the data be evaluated to validate the threshold values developed as a part of this study.
4. Although samples were not tested with PG asphalt cements with a high temperature grade above PG64, it is recommended that mixtures with PG70 or

PG76 asphalt cements be tested at 64°C. The same threshold limits of 5mm to prevent code 1 (> 6.35mm) rutting and 7mm to prevent code 2 (>12.7mm) rutting are recommended.

5. Additional research is needed to verify the threshold values recommended for higher PG grade asphalt cements (>PG70) and for special high stability mixtures such as those used at intersections.

IMPLEMENTATION

The results from this study are ready for immediate implementation. In fact, KDOT mixtures have been and are currently being evaluated using the APA. The current procedure should be continued with the above recommended threshold values being implemented. The current procedure has contractors submitting samples for APA testing to KU prior to final mix design approval. The procedure is coordinated through the Bureau of Materials and Research. It is recommended that this procedure be continued until the proposed simple performance tests from NCHRP 9-29 are ready for implementation. At that time a decision on the continuation of APA testing could be considered.

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APPENDIX

Standard Method of Test for

Determining Rutting Susceptibility Of Asphalt Paving Mixtures Using The Asphalt Pavement Analyzer (APA)

AASHTO Designation: TP xxx

1. SCOPE

1.1. This method describes a procedure for testing the rutting susceptibility of asphalt-aggregate mixtures using the Asphalt Pavement Analyzer (APA).

1.2. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- T 269, Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- T 312, Preparing and Determining the Density of the Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
- MP 2, Superpave Volumetric Mix Design
- PP 35, Evaluation of Superpave Gyratory Compactors (SGCs)
- R 30, Mixture Conditioning of Hot-Mix Asphalt (HMA)

3. APPARATUS

3.1. APA – A thermostatically controlled device designed to test the rutting susceptibility of asphalt-aggregate mixtures by applying repetitive linear loads to compacted test specimens through three pressurized hoses via wheels.

3.1.1. The APA shall be thermostatically controlled to maintain the test temperature and conditioning chamber at any set-point between 4° and 72°C (40° and 160°F) within 1°C (2°F).

3.1.2. The APA shall be capable of independently applying loads up to 534 N (120 lb_f.) to the three wheels. The loads shall be calibrated to the desired test load by an external-force transducer.

3.1.3. The pressure in the test hoses shall be adjustable and capable of maintaining a pressure up to 830 kPa (120 psi).

3.1.4. The APA shall be capable of testing six cylindrical specimens simultaneously.

3.1.5. The APA shall have a programmable master cycle counter that can be preset to the desired number of cycles for a test. The APA shall be capable of automatically stopping the test at the completion of the programmed number of cycles.

3.1.6. The hoses shall be as recommended by the APA manufacturer (such as a Gates 77B Paint Spray and Chemical, 19.0 mm (3/4 in.), 5.17 MPa (750 psi), W.P. GL 07148). The hoses should be replaced when any of the outer rubber casing has worn through and threads are exposed. Follow the APA manufacturer's instructions for the technique on replacing hoses.

3.2. Balance of 12,000-g capacity, accurate to 0.1-g.

3.3. Mixing utensils (bowls, spoon, spatula).

3.4. Ovens for heating aggregate and asphalt binder.

3.5. Superpave gyratory compactor (SGC) and molds conforming to AASHTO T 312.

4. PREPARATION OF TEST SPECIMENS

4.1. Number of Test Specimens – Six cylindrical (150 mm (6 in.) diameter x 75 mm (3 in.) tall) specimens.

4.2. Roadway Core Specimens

4.2.1. Roadway core specimens shall be 150 mm (6 in.) in diameter with all surfaces of the perimeter perpendicular to the surface of the core within 5 mm (0.2 in.). Cores shall be trimmed with a wet masonry saw to a height of 75 ± 3 mm (3.0±0.1 in.). If the core has a height of less than 72 mm (2.9 in.), plaster-of-Paris may be used to achieve the proper height. Testing shall be conducted on the uncut face of the core.

4.3. Plant-Produced Mixtures

4.3.1. Samples of plant-produced mixtures shall be obtained in accordance with AASHTO T 168. Mixture samples shall be reduced to the appropriate test size and compacted to the design number of gyrations (N_{des}) as determined in AASHTO MP 2 while the mixture is within the compaction range as determined by the binder supplier. Reheating of loose plant mixture should be avoided.

4.4. Laboratory-Prepared Mixtures

4.4.1. Mixture proportions are batched in accordance with the desired job mix formula.

4.4.2. The temperature to which the asphalt binder must be heated to achieve a viscosity of 170 ± 20 cSt shall be the mixing temperature. For modified asphalt binders, use the mixing temperature recommended by the binder manufacturer.

4.4.3. Dry-mix the aggregates and hydrated lime (if used) first; then add the correct percentage of asphalt binder. Mix the materials until all aggregates are thoroughly coated.

4.4.4. Test samples shall be conditioned at the appropriate compaction temperature in accordance with the short-term conditioning procedure in AASHTO R 30.

4.4.5. The temperature to which the asphalt binder must be heated to achieve a viscosity of 290 ± 30 cSt shall be the compaction temperature. For modified asphalt binders, use the compaction temperature recommended by the binder manufacturer.

4.5. Laboratory Compaction of Specimens

4.5.1. An SGC approved in accordance with AASHTO PP 35 should be used to compact the samples.

4.5.2. Compacted specimens should remain at room temperature, approximately 25°C (77°F), to allow the entire specimen to cool, for a minimum of three hours.

4.5.3. Laboratory-prepared specimens shall be compacted to N_{des} as determined in AASHTO MP 2 with a final height of 115 ± 5 mm (4.6 ± 0.2 in.). If the APA does not accommodate 115-mm (4.6 in.) compacted specimens, the specimens shall be sawed to a height of 75 ± 3 mm (3.0 ± 0.1 in). Only the bottom portion of the compacted specimens should be sawed off. The uncut side of the specimen shall be tested.

5. DETERMINING THE AIR VOID CONTENT

5.1. Determine the bulk specific gravity of the test specimens in accordance with AASHTO T 166.

5.2. Determine the maximum specific gravity of the test mixture in accordance with AASHTO T 209.

5.3. Determine the air void content of the test specimens in accordance with AASHTO T 269.

6. SELECTING THE TEST TEMPERATURE

6.1. The test temperature shall be set to the high temperature of the standard Superpave binder Performance Grade (PG) for the specifying agency. For circumstances where the binder grade has been "bumped," the APA test temperature will remain at the standard PG high temperature.

7. SPECIMEN PREHEATING

7.1. Place the specimens in the molds.

7.2. Specimens shall be preheated in the temperature-calibrated APA test chamber or a separate calibrated oven for a minimum of 6 hours. Specimens should not be held at elevated temperatures for more than 24 hours prior to testing.

8. PROCEDURE

8.1. Set the hose pressure gap reading to 700 ± 35 kPa (100 ± 5 psi). Set the load cylinder pressure reading for each wheel to achieve a load of 445 ± 22 N (100 ± 5 lb_f.).

8.2. Stabilize the testing chamber temperature at the temperature selected in Section 6.

8.3. Secure the preheated, molded specimens in the APA. The preheated APA chamber should not be open more than six minutes when securing the test specimens into the machine. Close the chamber doors, and allow ten minutes for the temperature to re-stabilize prior to starting the test.

8.4. Apply 25 cycles to seat the specimens before the initial measurements. Make adjustments to the hose pressure as needed during these 25 cycles.

8.5. Open the chamber doors; unlock and pull out the sample holding tray.

8.6. Place the rut-depth-measurement template over the specimen. Make sure that the rut-depth-measurement template is properly seated and firmly rests on top of the testing mold.

8.7. Zero the digital measuring gauge so that the display shows "0.00" with the gauge completely extended. The display should also have a bar below the "inc." position. Take initial readings at each of the four outside locations on the template. The center measurement is not used for cylindrical specimens. Measurements shall be determined by placing the digital measuring gauge in the template slots and sliding the gauge slowly across the each slot. Record the smallest measurement for each location to the nearest 0.01 mm (0.004 in.).

8.8. Repeat Subsections 8.6. and 8.7. for each set of cylinders in the testing position. All measurements shall be completed within 6 $\pm$ 0.5 minutes.

8.9. Push the sample holding tray in, and secure it. Close the chamber doors, and allow ten minutes for the temperature to equalize.

8.10. Set the PRESET COUNTER to 8000 cycles.

8.11. Start the test. When the test reaches 8000 cycles, the APA will stop, and the load wheels will automatically retract.

8.12. Repeat Subsections 8.5 through 8.8 to obtain the final measurements.

Note 1 - Some APA's have been equipped with automatic measurement systems that make Subsections 8.5 through 8.9 unnecessary. Some APA users have reported significant differences in rut depths between the automatic measurements and manual measurements.

9. CALCULATIONS

9.1. The rut depth at each location is determined by subtracting the final measurement from the initial measurement.

9.2. Determine the overall average rut depth for each test position. Use the average of all 12 measurements to calculate the average rut depth.

9.3. Calculate the average rut depth from the three test positions. Also, calculate the standard deviation for the three test positions.

9.4. Outlier Evaluation – If the standard deviation of the set is greater than or equal to 2.0 mm (0.08 in.), then the position with the rut depth farthest from the average may be discarded. The testing procedure, device calibration, and test specimens should be investigated to determine possible causes for the excessive variation.

9.5. The APA rut depth for the mixture is the average of the rut depth for the six cylindrical specimens at 8000 cycles.

10. REPORT

10.1. The test report shall include the following information:

10.1.1. The laboratory name, technician name, and date of the test.

10.1.2. The mixture type and description.

10.1.3. The average air void content of the test specimens.

10.1.4. The test temperature.

10.1.5. The average rut depth, to the nearest 0.1 mm (0.04 in.), at 8000 cycles.

11. PRECISION AND BIAS

11.1. Work is underway to develop precision and bias statements for this standard.

ANNEX

(Mandatory Information)

A. CALIBRATION

The following items should be checked for calibration no less than once per year: (1) preheating over, (2) APA temperature, (3) APA wheel load, and (4) APA hose pressure. Instructions for each of these calibration checks are included in this section.

A.1. Temperature calibration of the preheating oven.

A1.1. The preheating oven must be calibrated with a NIST-traceable thermometer (an ASTM 65°C calibrated thermometer is recommended) and a metal thermometer well to avoid rapid heat loss when checking the temperature.

A1.2. Temperature Stability

A.1.2.1. Set the oven to the chosen temperature (e.g., 67°C). Place the thermometer in the well, and place the thermometer and well on the center of the shelf where the samples and molds will be preheated. It usually takes an hour or so for the oven chamber, well, and thermometer to stabilize. After one hour, open the oven door, and read the thermometer without removing it from the well. Record this temperature. Close the oven door.

A.1.2.2. Thirty minutes after obtaining the first reading, obtain another reading of the thermometer. Record this temperature.

A.1.2.3. If the readings from Subsection A.1.2.1 and A.1.2.2 are within 0.4°C, then average the readings. If the readings differ by more than 0.4°C (0.8°F), then continue to take readings every 30 minutes until the temperature stabilizes within 0.4°C (0.8°F) on two consecutive readings.

A1.3. Temperature Uniformity

A.1.3.1. To check the uniformity of the temperature in the oven chamber, move the thermometer and well to another location in the oven so that they are on a shelf where the samples and molds will be preheated, but as far as possible from the first location. Take and record readings of the thermometer at the second location every 30 minutes until two consecutive readings at the second location are within 0.4°C (0.8°F).

A.1.3.2. Compare the average of the two readings at the first location with the average of the stabilized temperature at the second location. If the average temperatures from the two locations are within 0.4°C (0.8°F), then the oven temperature is relatively uniform, and it is suitable for use in preheating APA samples. If the average of the readings at the two locations differ by more than 0.4°C (0.8°F), then another oven that will hold this level of uniformity and meet calibration must be utilized.

A1.4. Temperature Accuracy

A.1.4.1. Average the temperatures from the two locations. If that average temperature is within 0.4°C (0.8°F) of the set-point temperature on the oven, then the oven is reasonably accurate and calibration is complete.

A.1.4.2. If the set point differs from the average temperature by more than 0.4°C (0.8°F), then adjust the oven set point appropriately to raise or lower the temperature inside the oven chamber so that the thermometer and well will be at the desired temperature (e.g., 67°C).

A.1.4.3. Place the thermometer and well on the center of the shelf. At 30-minute intervals, take readings of the thermometer. When two consecutive readings are within 0.4°C (0.8°F), and the average of the two consecutive readings are within 0.4°C (0.8°F) of the desired test temperature (e.g., 67°C), then the oven has been properly adjusted and calibration is complete. If these two conditions are not satisfied, then repeat Subsections A.1.4.2 and A.1.4.3.

A.2. APA Temperature Calibration.

A2.1. The APA must be calibrated with a NIST-traceable thermometer (an ASTM 65°C calibrated thermometer is recommended) and a metal thermometer well to avoid rapid heat loss when checking the temperature.

A2.2. Temperature Stability

A.2.2.1. Turn on the APA main power, and set the chamber temperature controller so that the inside of the testing chamber is at the anticipated testing temperature (e.g., 67°C). Also, set the water temperature controller to achieve the anticipated testing temperature. **Note A1 -** Experience has shown that the temperature controller on the APA is not always accurate. The thermometer should always be considered chamber temperature.

A.2.2.2. Place the thermometer in the well, and place the thermometer and well on the left side of the APA where the samples are tested. **Note A2 -** It may be helpful to remove the hose rack from the APA during the temperature calibration to avoid breaking the thermometer.

A.2.2.3. It usually takes about five hours for the APA to stabilize. After the temperature display on the controller has stabilized, open the chamber doors, and read the thermometer without removing it from the well. Record this temperature. Close the chamber doors.

A.2.2.4. Thirty minutes after obtaining the first reading, obtain another reading of the thermometer. Record this temperature.

A.2.2.5. If the readings from Subsections A.2.2.2 and A.2.2.4 are within 0.4°C (0.8°F), then average the readings. If the readings differ by more than 0.4°C (0.8°F), then continue to take readings every thirty minutes until the temperature stabilizes within 0.4°C (0.8°F) on two consecutive readings.

A2.3. Temperature Uniformity

A.2.3.1. To check the uniformity of the temperature in the APA chamber, move the thermometer and well to the right side of the APA where the samples are tested. Take and record readings of the thermometer at the second location every 30 minutes until two consecutive readings at the second location are within 0.4°C (0.8°F).

A.2.3.2. Compare the average of the two readings obtained in Subsections A.2.2.5 and A.2.3.1. If the average temperatures from the two locations are within 0.4°C (0.8°F), then the APA temperature is relatively uniform, and it is suitable for use. If the average of the readings at the two locations differ by more than 0.4°C (0.8°F), then consult with the manufacturer on improving the temperature uniformity.

A2.4. Temperature Accuracy

A.2.4.1. Average the temperatures from the two locations. If that average temperature is within 0.4°C (0.8°F) of the desired test temperature (e.g., 67°C), then the APA temperature is reasonably accurate and calibration is complete.

A.2.4.2. If the average temperature differs from the desired test temperature (e.g., 67°C) by more than 0.4°C (0.8°F), then adjust the APA temperature controller so that the thermometer and well will be at the desired test temperature. **Note A3** - It is advisable to keep the water bath set at the same temperature as the test chamber.

A.2.4.3. Place the thermometer and well on the center of the shelf. At 30-minute intervals, take readings of the thermometer. When two consecutive readings are within 0.4°C (0.8°F), and the average of the two consecutive readings are within 0.4°C (0.8°F) of the desired test temperature (e.g., 67°C), then the APA temperature has been properly adjusted and calibration at that temperature is complete. Record the current set points on the temperature controllers for later reference. If these two conditions are not satisfied, then repeat Subsections A.2.4.2 and A.2.4.3.

A.3. APA wheel load calibration of the air cylinders at the three test positions.

A3.1. The APA wheel loads will be checked with the calibrated load cell provided with the APA. The loads will be checked and adjusted one at a time while the other wheels are in the "down" position and bearing on a dummy sample or wooden block of approximately the same height as a test sample. Calibration of the wheel loads should be accomplished with the APA at room temperature.

A.3.1.1. Remove the hose rack from the APA.

A.3.1.2. "Jog" the wheel carriage until the wheels are over the center of the sample tray when the wheels are in the "down" position.

A.3.1.3. Raise and lower the wheels 20 times to heat up the cylinders.

A.3.1.4. Adjust the bar on top of the load cell by screwing it in or out until the total height of the load cell-load bar assembly is 105 $\pm$ 5 mm (4.2 $\pm$ 0.2 in.).

A.3.1.5. Position the load cell under one of the wheels. Place wooden blocks or dummy samples under the other two wheels.

A.3.1.6. Zero the load cell.

A.3.1.7. Lower all wheels by turning the cylinder switch to "CAL."

A.3.1.8. If the load cell is not centered left-to-right beneath the wheel, then raise the wheel, and adjust the position of the load cell. To determine if the load cell is centered front-to-back beneath the wheel, unlock the sample tray, and move it SLOWLY until the wheel rests in the indentation on the load cell bar (where the screw is located).

A.3.1.9. After the load cell has been properly centered, adjust the pressure in the cylinder to obtain 445 ± 5 N (100 ± 1 lb_f). Allow three minutes for the load-cell reading to stabilize between adjustments. Record the pressure and load.

A.3.1.10. With the wheel on the load cell remaining in the "down" position, raise and lower the other wheels one time. Allow three minutes for the load-cell reading to stabilize. Record the pressure and load.

A.3.1.11. With the other wheels remaining in the "down" position, raise and lower the wheel over the load-cell. Allow three minutes for the load cell reading to stabilize. Record the pressure and load.

A.3.1.12. Repeat Subsections A.3.1.5 through A.3.1.11 for each wheel/cylinder.

A.3.1.13. Return the load cell to the first wheel, and repeat Subsections A.3.1.5 through A.3.1.11.

A.3.1.14. Place the load cell under the second wheel, and repeat Subsections A.3.1.5 through A.3.1.11.

A.3.1.15. Place the load cell under the third wheel, and repeat Subsections A.3.1.5 through A.3.1.11. The current cylinder pressures will be used to set the wheel loads to 445 N (100 lb_f).

A.4. Replacement of the APA hoses.

A4.1. New hoses shall be placed in service in accordance with Subsection 3.1.6.

A.4.1.1. Remove the hose rack from the APA.

A.4.1.2. Remove the used hoses from the hose rack. For each position, place the new hose on the barbed nipples, and secure it with the hose clamps.

A.4.1.3. Position the hoses in the rack such that the hose curvature is vertical. Tighten the nuts at the ends of the hoses only until the hoses are secure. Over-tightening will affect the contact pressure and hose life.

A.4.1.4. Place the hose rack back into the APA, and ensure that the hoses are aligned beneath the wheels.

A.4.1.5. Prior to formal testing, "break in" the new hoses by running 8000 cycles on a set of previously tested samples at a temperature of 55°C (131°F) or higher.

A.5. APA hose pressure check.

A5.1. The air pressure in the APA test hoses shall be checked with a NIST-traceable test gauge or transducer with a suitable range while the APA is operating. Since the hoses are connected in series, it is satisfactory to connect the test gauge to the end of the right-most hose. The pressure should not fluctuate outside of the range of 690 ± 35 kPa (100 ± 3 psi) during normal operation. Adjust the pressure as necessary with the hose-pressure regulator.

Note A4 - The Ashcroft test gauge, Model 450182As02L200#, has been found to be satisfactory for this purpose. This gauge may be available through Grainger (Stock No. 2F008).