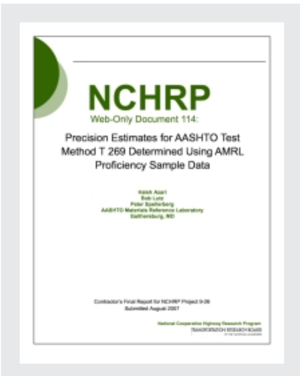

Precision Estimates for AASHTO Test Method T 269 Determined Using AMRL Proficiency Sample Data

DETAILS

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ACKNOWLEDGMENTS

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CHAPTER 1. INTRODUCTION AND RESEARCH APPROACH

1.1 INTRODUCTION

Under National Cooperative Highway Research Programs (NCHRP) Project 9-26, the AASHTO Materials Reference Laboratory (AMRL) is conducting a multi-phase research project to improve estimates of precision in AASHTO test methods for asphalt binder and hot-mix asphalt (HMA). The report from Phase 1 of Project 9-26 includes precision estimates of selected volumetric properties of HMA using non-absorptive aggregates [1]. The report from Phase 2 discusses the results of an investigation into the cause of variations in HMA bulk specific gravity test results using non-absorptive aggregates [2]. The report from Phase 3 includes a robust technique developed by AMRL for analyzing proficiency sample data for the purpose of obtaining reliable single-operator and multilaboratory estimates of precision [3]. The report from phase 4 includes two parts. Part one covers the precision estimates of selected volumetric properties of HMA using absorptive aggregates. Part two of the report investigates the effect of aging period on the volumetric properties of the absorptive aggregates [4]. This report includes the results of Phase 5 of NCHRP 9-26 where data from the AMRL Proficiency Sample Program (PSP) are used to update precision estimates for AASHTO Standard Test Method T269, “Percent Air Voids in Compacted Dense and Open Asphalt Mixtures” [5].

Laboratories participating in the AMRL Proficiency Program receive annual or biannual shipments of paired proficiency samples which are tested according to specified AASHTO test methods [6,7]. The results of the testing are returned to AMRL for analysis, summarization, and reporting back to the laboratories. AMRL has an extensive database of test results for the broad range of construction materials included in its proficiency sample program. Data used in this study are for Hot-Mix Asphalt Gyratory and Hot-Mix Design samples (HMD). The Hot-Mix Asphalt Gyratory samples (HMG) were compacted by means of the Superpave Gyratory Compactor (T312) [8]. The Hot-Mix Asphalt Design samples were compacted by means of the Marshall Apparatus (T245) [9], California Kneading Compactor (T247) [10], or the Gyratory Shear Compactor (D4013) [11]. The proficiency samples included in these programs cover a range of test values and grades of materials.

The technique developed by AMRL in Phase 3 was utilized for analyzing proficiency sample data. This technique is a four step methodology for shaving off extraneous results and analyzing the core data of a paired data set. The results of the analysis of the “core data” can then be used to obtain reliable single-operator and multilaboratory estimates of precision.

In this study, 12 paired data sets were analyzed resulting in a precision statement for Percent Air Voids test method that reflects the various means of compaction. Only the most recent proficiency samples were used in order to account for changes in test precision resulting from recent improvements in the test methods.

1.1.1 Problem Statement

AASHTO Standard Test Methods applicable to highway materials require periodic studies to determine estimates of precision. Some precision estimates become outdated as a result of improvements in the methods while other estimates need to be verified to see if they are still accurate. Others need to be expanded to take into account a wider range of materials while some newer test methods may not have precision estimates of any kind. This study provides a precision estimate for the percent air voids of dense graded asphalt mixtures with nonporous aggregate, which is based on the most recent version of the test method and incorporates various methods of compaction currently employed.

1.1.2 Research Objectives

The objective of Phase 5 of NCHRP Project 9-26, herein referred to as the Phase 5 study, is to update single-operator and multilaboratory precision estimates for the following test method:

AASHTO T269 — Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

The resulting precision estimates will reflect four different compaction methods which are included in the scope of the AMRL Proficiency Sample Program. The compaction methods are:

1. AASHTO T245 — Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
2. AASHTO T247 — Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor
3. AASHTO T312 — Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
4. ASTM D4013 — Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor

1.2 SCOPE OF STUDY

This work is limited to an evaluation of data collected from laboratories participating in the Hot-Mix Asphalt Superpave Gyratory (HMG) and Hot-Mix Asphalt Design (HMD) portions of the AMRL Proficiency Sample Program. There are 12 data sets analyzed and included in this report.

1.3 PROFICIENCY SAMPLES USED IN STUDY

Included in the study are the most recent AMRL proficiency samples for the test methods covered in the Research Objectives (Section 1.1.2). These samples include multiple grades of material when it was possible to do so. The following are descriptions of the pertinent information for the samples used. There are no modified binders used in the analysis. The details of the Hot-Mix Asphalt Design (HMD) samples are listed in Table 1-1. The samples in Table 1-1 were compacted by means of the Marshall Apparatus, the California Kneading Compactor, and the Gyratory Shear Compactor.

Table 1-1- HMD Proficiency Samples Used in Analysis of T269 Precision Estimates

Sample Designation	Performance Grade	Date of Final Report	Modified Binder
HMD 41 & 42	PG 70-22	August 2004	No
HMD 43 & 44	PG 64-10	August 2005	No
HMD 45 & 46	PG 64-22	August 2006	No

The details of the Hot-Mix Asphalt Superpave Gyratory Compactor [HMG] samples are listed in Table 1-2. The Superpave Gyratory Compactor is the only means of compaction associated with these samples.

Table 1-2- HMG Proficiency Samples Used in Analysis of T269 Precision Estimates

Sample Designation	Performance Grade	Date of Final Report	Modified Binder
HMG 17 & 18	PG 70-22	August 2004	No
HMG 19 & 20	PG 64-10	August 2005	No
HMG 21 & 22	PG 64-22	August 2006	No

CHAPTER 2. RESULTS OF ANALYSIS AND ESTIMATES OF PRECISION

2.1 TEST DATA

The individual results for each of the 12 proficiency data sets used to create precision estimates can be found in Appendices A to D. This chapter includes summaries of the data and the resulting precision estimates.

2.2 ANALYSIS OF THE DATA

The precisions of T 269 were computed using the precision of the percent air voids that were analyzed for each of the four means of compaction included in this study. The precisions were also computed using the precisions of the bulk specific gravity and theoretical maximum specific gravity following the procedure explained in Section 8.1 of AASHTO T 269 test method. The precision estimates are based, where appropriate, on either the coefficients of variation (CV %) or the pooled standard deviation (1s) values. The following sections provide the results of the analyses.

2.2.1 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus, AASHTO T245

The precision limits for percent air voids from analyzing the percent air void data of asphalt mixtures compacted by means of the Marshall Apparatus are found in Table 2-1 and the plot of the individual data are found in Appendix A. The precision limits for percent air voids were also obtained from analyzing the bulk (G_{mm}) and maximum (G_{mb}) specific gravities of the mixtures. Following the procedure in Section 8.1 of AASHTO T 269 test method, the precisions of G_{mm} and G_{mb} in Table 2-2 were used to compute the precisions for percent air voids in Table 2-3. The comparison of the repeatability and reproducibility statistics in Table 2-1 and Table 2-3 indicates that for the samples compacted by the Marshall method the precisions computed using the air void data are not significantly different from the precisions computed using G_{mm} and G_{mb} data.

Table 2-1- Precisions of % Air voids based on Analysis of Air Void Data (Marshall Apparatus)

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples	Odd Samples		Even Samples	
						1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	508	77-22	5.53	5.58	0.58	10.5	10.4	1.24	22.5	1.26	22.6
HMD	43 & 44	532	64-10	5.6	5.65	0.50	8.9	10.8	0.95	17.0	0.97	20.8
HMD	45 & 46	578	64-22	3.30	3.14	0.33	10.1	10.6	0.94	28.6	0.93	29.6

Table 2-2- Summary Table for Precisions of G_{mm} & G_{mb} (Marshall Apparatus)

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability	Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples
						1s	1s	1s
HMD Gmm	41 & 42	576	70-22	2.644	2.634	0.0055	0.0087	0.0094
HMD Gmm	43 & 44	557	64-10	2.657	2.608	0.0046	0.0075	0.0070
HMD Gmm	45 & 46	541	64-22	2.555	2.557	0.0047	0.0078	0.0078
HMD Gmb	41 & 42	533	70-22	2.496	2.484	0.0142	0.0314	0.0307
HMD Gmb	43 & 44	564	64-10	2.506	2.486	0.0118	0.0233	0.0251
HMD Gmb	45 & 46	593	64-22	2.471	2.477	0.0074	0.0213	0.0216

Table 2-3- Precisions of % Air Voids based on Analysis of G_{mm} & G_{mb} Data (Marshall Apparatus)

Sample Type	Sample Number	Repeatability	Reproducibility	
			Odd Samples	Even Samples
		1s	1s	1s
HMD	41 & 42	0.57	1.23	1.21
HMD	43 & 44	0.48	0.92	1.00
HMD	45 & 46	0.34	0.88	0.90

A review of the data shown in Table 2-1 and Table 2-3 indicates that the form of the precision estimates should be based on the sample standard deviation. Therefore, the pooled repeatability and reproducibility were computed using sample standard deviations and provided in Table 2-4. The pooled repeatability and pooled reproducibility are derived using the following equation from Ku [11]:

$$s_p = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2 + \ldots + (n_k-1)s_k^2}{n_1 + n_2 + \ldots + n_k - k}} \qquad \text{(Equation 1)}$$

Where:

s_p = pooled standard deviation

s_k = k[th] standard deviation

n_k = number of laboratories analyzed resulting in k[th] standard deviation

Table 2-4- Pooled Precisions for T269 using Precisions of % Air Voids and Precisions of G_{mm} & G_{mb} (Marshall Apparatus)

Data Type	Pooled Repeatability	2ds	Pooled Reproducibility	2ds
HMD Air voids	0.48	1.36	1.08	3.06
HMD Gmb & Gmm	0.47	1.33	1.03	2.91

As it is observed from Table 2-4, the pooled repeatability and reproducibility precision computed from G_{mm} and G_{mb} data and from the air void data are not significantly different. This indicates that the values that were considered as outliers in air void data were also considered outliers in G_{mm} and G_{mb} data.

2.2.2 Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor, AASHTO T247

The precisions resulting from analysis of the percent air void data for specimens compacted by means of the California Kneading Compactor are found in Table 2-5 and Appendix B. The precision limits for percent air voids were also obtained from analyzing the bulk (G_{mm}) and maximum (G_{mb}) specific gravities of the mixtures. Following the procedure in Section 8.1 of AASHTO T 269 test method, the precisions of G_{mm} and G_{mb} in Table 2-6 were used to compute the precisions of percent air voids for each set of the paired samples in Table 2-7.

Table 2-5- Precisions of % Air Voids based on Analysis of Air Void Data (California Kneading Compactor)

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples	Odd Samples		Even Samples	
						1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	60	70-22	7.40	6.94	0.61	8.2	8.8	1.62	21.9	1.69	24.4
HMD	43 & 44	69	64-10	5.75	5.50	0.53	9.2	9.7	1.15	20.0	1.22	22.1
HMD	45 & 46	75	64-22	3.67	3.80	0.41	11.3	10.9	0.98	26.6	1.00	26.3

Table 2-6- Summary Table for Precisions of G_{mm} & G_{mb} (California Kneading Compactor)

Sample Type	Sample Number	No. of Labs	PG Grade	Average Results		Repeatability	Reproducibility	
				Odd Samples	Even Samples	1s	Odd Samples	Even Samples
							1s	1s
HMD G_{mm}	41 & 42	497	70-22	2.644	2.634	0.006	0.009	0.009
HMD G_{mm}	43 & 44	59	64-10	2.658	2.607	0.004	0.008	0.007
HMD G_{mm}	45 & 46	68	64-22	2.554	2.560	0.004	0.009	0.008
HMD G_{mb}	41 & 42	64	70-22	2.438	2.443	0.017	0.042	0.04
HMD G_{mb}	43 & 44	72	64-10	2.501	2.465	0.011	0.027	0.026
HMD G_{mb}	45 & 46	78	64-22	2.459	2.458	0.010	0.021	0.022

Table 2-7- Precisions of % Air Voids based on Analysis of G_{mm} & G_{mb} Data (California Kneading Compactor)

Sample Type	Sample Number	Repeatability	Reproducibility	
		1s	Odd Samples	Even Samples
			1s	1s
HMD	41 & 42	0.68	1.62	1.55
HMD	43 & 44	0.44	1.05	1.03
HMD	45 & 46	0.43	0.90	0.92

A review of the data shown in Table 2-5 and Table 2-7 indicates that the form of the precision estimates should be based on the sample standard deviation. Therefore, the pooled repeatability and reproducibility were computed using sample standard deviations and are provided in Table 2-8. The pooled repeatability and pooled reproducibility are derived using Equation 1.

As it is observed from Table 2-8, the pooled repeatability precision computed from G_{mm} and G_{mb} data is significantly larger than the pooled repeatability precision computed from the air void data. However, the pooled reproducibility precisions from the two cases are not significantly different. This indicates that in the analysis of the single operator precision, a smaller number of outliers were identified in the G_{mm} and G_{mb} data than in the air void data. Therefore, specifying a precision limit based on specific gravities might result in accepting the air void values that are in fact out of the practical range for the air voids.

Table 2-8- Pooled Precisions for T269 using Precisions of % Air Voids and Precisions of G_{mm} & G_{mb} (California Kneading Compactor)

Data Type	Pooled Repeatability	2ds	Pooled Reproducibility	2ds
HMD Air voids	0.52	1.47	1.39	3.93
HMD Gmb & Gmm	0.61	1.73	1.41	3.99

2.2.3 Standard Practice for Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor, ASTM D4013

The precisions resulting from analysis of percent air voids for specimens compacted by means of the Gyratory Shear Compactor are found in

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
							Odd Samples	Even Samples	Odd Samples		Even Samples	
				Odd Samples	Even Samples	1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	20	70-22	5.25	4.92	0.62	11.7	12.5	1.74	33.2	2.02	41.0
HMD	43 & 44	22	64-10	5.44	4.65	0.48	8.8	10.3	1.17	21.5	1.59	34.3
HMD	45 & 46	25	64-22	4.20	4.17	0.39	9.2	9.3	0.93	22.08	0.90	21.6

and Appendix C. The precision limits for percent air voids were also obtained from analyzing the bulk (G_{mm}) and maximum (G_{mb}) specific gravities of the mixtures. Following the procedure in Section 8.1 of AASHTO T 269 test method, the precisions of G_{mm} and G_{mb} in Table 2-10 were used to compute the precisions of percent air voids in Table 2-11. The comparison of the repeatability and reproducibility statistics in

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
							Odd Samples	Even Samples	Odd Samples		Even Samples	
				Odd Samples	Even Samples	1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	20	70-22	5.25	4.92	0.62	11.7	12.5	1.74	33.2	2.02	41.0
HMD	43 & 44	22	64-10	5.44	4.65	0.48	8.8	10.3	1.17	21.5	1.59	34.3
HMD	45 & 46	25	64-22	4.20	4.17	0.39	9.2	9.3	0.93	22.08	0.90	21.6

and Table 2-11 indicates that in some cases the two methods of analysis provide significantly different precision limits. However, any clear trends in the differences are not observed.

Table 2-9- Precisions of % Air Voids based on Analysis of Air Void Data (Gyratory Shear Compactor)

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples	Odd Samples		Even Samples	
						1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	20	70-22	5.25	4.92	0.62	11.7	12.5	1.74	33.2	2.02	41.0
HMD	43 & 44	22	64-10	5.44	4.65	0.48	8.8	10.3	1.17	21.5	1.59	34.3
HMD	45 & 46	25	64-22	4.20	4.17	0.39	9.2	9.3	0.93	22.08	0.90	21.6

Table 2-10- Summary Table for Precisions of G_{mm} & G_{mb} (Gyratory Shear Compactor)

Sample Type	Sample Number	No. of Labs	PG Grade	Average Results		Repeatability	Reproducibility	
				Odd Samples	Even Samples	1s	Odd Samples	Even Samples
							1s	1s
HMD G_{mm}	41 & 42	497	70-22	2.644	2.634	0.006	0.009	0.009
HMD G_{mm}	43 & 44	21	64-10	2.658	2.607	0.006	0.008	0.007
HMD G_{mm}	45 & 46	19	64-22	2.5565	2.5561	0.003	0.0056	0.0064
HMD G_{mb}	41 & 42	21	70-22	2.498	2.503	0.013	0.055	0.056
HMD G_{mb}	43 & 44	23	64-10	2.514	2.49	0.01	0.03	0.038
HMD G_{mb}	45 & 46	24	64-22	2.449	2.4513	0.0074	0.0203	0.0232

Table 2-11- Precisions of % Air Voids based on Analysis of G_{mm} & G_{mb} Data (Gyratory Shear Compactor)

Sample Type	Sample Number	Repeatability	Reproducibility	
		1s	Odd Samples	Even Samples
			1s	1s
HMD	41 & 42	0.538	2.105	2.151
HMD	43 & 44	0.406	1.164	1.478
HMD	45 & 46	0.311	0.821	0.939

A review of the data shown in

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples	Odd Samples		Even Samples	
						1s	CV%	CV%	1s	CV%	1s	CV%
HMD	41 & 42	20	70-22	5.25	4.92	0.62	11.7	12.5	1.74	33.2	2.02	41.0
HMD	43 & 44	22	64-10	5.44	4.65	0.48	8.8	10.3	1.17	21.5	1.59	34.3
HMD	45 & 46	25	64-22	4.20	4.17	0.39	9.2	9.3	0.93	22.08	0.90	21.6

and Table 2-11 indicates that the form of the precision estimates should be based on the sample standard deviation. Therefore, the pooled repeatability and reproducibility were computed using sample standard deviations and are provided in Table 2-12. The pooled repeatability and pooled reproducibility are derived using Equation 1.

As it is observed from Table 2-12, the pooled repeatability precision computed from specific gravities and percent air void are not significantly different. However, the pooled reproducibility precision from G_{mm} and G_{mb} data is significantly larger than the pooled reproducibility from air void data. This indicates that in the analysis of the multilaboratory precision, a smaller number of outliers were identified in the G_{mm} and G_{mb} data than in the air void data. Therefore, specifying a precision limit based on specific gravities might result in accepting the air void values that are in fact out of the practical range for the air voids.

Table 2-12- Pooled Precisions for T269 using Precisions of % Air Voids and Precisions of G_{mm} & G_{mb} (Gyratory Shear Compactor)

Data Type	Pooled Repeatability	2ds	Pooled Reproducibility	2ds
HMD Air voids	0.50	1.42	1.49	4.22
HMD Gmb & Gmm	0.52	1.47	2.02	5.72

2.2.4 Preparing and Determining the Density of the Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor, AASHTO T312

The precisions resulting from analysis of percent air void data for specimens compacted by means of the Superpave Gyratory Compactor are found in Table 2-13 and Appendix D. The precision limits for percent air voids were also obtained from analyzing the bulk (G_{mm}) and maximum (G_{mb}) specific gravities of the mixtures. Following the procedure in Section 8.1 of AASHTO T 269 test method, the precisions of G_{mm} and G_{mb} in Table 2-14 were used to compute the precision of percent air voids in Table 2-15. The comparison of the repeatability and reproducibility statistics in Table 2-13 and Table 2-15 indicates that two methods of analysis provide comparable precision limits.

A review of the data shown in Table 2-13 and Table 2-15 indicates that the form of the precision estimates should be based on the sample standard deviation. Therefore, the pooled repeatability and reproducibility were computed using sample standard deviations and are provided in Table 2-16. The pooled estimates are derived using Equation 1.

As it is observed from Table 2-16, the pooled repeatability precision computed from G_{mm} and G_{mb} data is not significantly different from the pooled repeatability precision computed from the air void data. The pooled reproducibility precision from G_{mm} and G_{mb} data is smaller than the pooled reproducibility computed using air void data but not significantly.

Table 2-13- Precisions of % Air Voids based on Analysis of % Air Void Data (Superpave Gyratory Compactor)

Sample Type	Sample Number	No. of Labs	Grade	Average Results		Repeatability			Reproducibility		Reproducibility	
				Odd Samples	Even Samples		Odd Samples	Even Samples	Odd Samples		Even Samples	
						1s	CV%	CV%	1s	CV%	1s	CV%
GYR	17 & 18	358	70-22	7.95	6.68	0.59	7.37	8.77	1.13	14.20	1.10	16.44
GYR	19 & 20	396	64-10	4.55	4.19	0.49	10.82	11.73	0.90	19.84	0.91	21.61
GYR	21 & 22	435	64-22	2.69	2.37	0.32	12.0	13.6	0.79	29.2	0.74	31.2

Table 2-14- Summary Table for Precisions of G_{mm} & G_{mb} (Superpave Gyratory Method)

Sample Type	Sample Number	No. of Labs	PG Grade	Average Results		Repeatability	Reproducibility	
				Odd Samples	Even Samples	1s	Odd Samples	Even Samples
							1s	1s
GYR G_{mm}	17 & 18	398	70-22	2.6455	2.6348	0.0060	0.0101	0.0091
GYR G_{mm}	19 & 20	415	64-10	2.6607	2.6093	0.0060	0.0084	0.0081
GYR G_{mm}	21 & 22	430	64-22	2.5593	2.5620	0.0037	0.0060	0.0053
GYR G_{mb}	17 & 18	392	70-22	2.4333	2.4584	0.0138	0.0277	0.0282
GYR G_{mb}	19 & 20	424	64-10	2.5404	2.5003	0.0132	0.0240	0.0250
GYR G_{mb}	21 & 22	448	64-22	2.4913	2.5018	0.0069	0.0173	0.0167

Table 2-15- Precisions of % Air Voids based on Analysis of G_{mm} & G_{mb} Data (Superpave Gyratory Method)

Sample Type	Sample Number	Repeatability	Reproducibility	
		1s	Odd Samples	Even Samples
			1s	1s
GYR	17 & 18	0.56	1.10	1.12
GYR	19 & 20	0.55	0.95	1.00
GYR	21 & 22	0.30	0.71	0.68

Table 2-16- Pooled Precisions for T269 using Precisions of % Air voids and Precisions of G_{mm} & G_{mb} (Superpave Gyratory Method)

Data Type	Pooled Repeatability	2ds	Pooled Reproducibility	2ds
HMG Air voids	0.47	1.33	1.01	2.86
HMG Gmb & Gmm	0.48	1.36	0.94	2.66

CHAPTER 3. COMPARISON OF AVAILABLE PRECISION ESTIMATES

To examine the reliability of the precision limits obtained in this study, two sets of comparisons were made. The first comparison is between the computed precision limits and the precision limits that are currently available in Section 8.3 of AASHTO T 269. The second comparison is between the precision limits from Superpave Gyratory Compactor data (AASHTO T312) as part of this study and the precision limits for AASHTO T312 determined in Phase 1 of the NCHRP 9-26 project [1].

Table 3-1 shows the proposed precision limits for AASHTO T 269 from this study using the Professional Sample Program (PSP) Data for various methods of compaction. The current precisions in Section 8.3 of T 269 are also presented in the table. The comparison of the proposed and current precision limits indicates that the single operator precisions from the two sources are reasonably consistent. Also, the proposed multilaboratory precisions derived from Marshall Apparatus and Superpave Gyratory Compactor data are consistent with the multilaboratory precision limit in Section 8.3 of T 269. However, the multilaboratory precisions derived from California Kneading and Shear Gyratory Compactor data are significantly larger than the current precision in T269. It is speculated that the reason for this significant difference is because these two compaction methods were not included in the development of the current T269 precisions.

Table 3-1 also provides the precision estimates for the air voids of the specimens compacted according to AASHTO T 312 as part of the interlaboratory study (ILS) in Phase 1 of the NCHRP 9-26 project [1]. As indicated from the table, the multilaboratory precision obtained from Superpave Gyratory Compactor data in this study is significantly larger than the multilaboratory precision from Phase 1. The reason for this could be the difference in the preparation of the specimens in each study. The PSP specimens for this study were mixed and compacted at the participating laboratories; however, the specimens for the ILS in Phase 1 were mixed in AMRL laboratory and compacted at different laboratories. Therefore, it seems reasonable that the multilaboratory precision from PSP to be larger than that from ILS.

Table 3-1- Summary of the Available Precision Estimates for T269

Data Type	Single operator Precision	2ds	Multilaboratory Precision	2ds
Marshall (Phase 5)	0.48	1.35	1.08	3.06
California Kneading (Phase 5)	0.52	1.46	1.39	3.94
Shear Gyratory (Phase 5)	0.50	1.41	1.49	4.22
Superpave Gyratory (Phase 5)	0.47	1.33	1.01	2.87
AASHTO T269 (Sec. 8.3)	0.51	1.44	1.09	3.08
ILS (Phase 1 NCHRP 9-26)	0.30[1]- 0.50[2]	0.90[1]- 0.140[2]	0.60	1.70

[1] 12.5-mm nominal maximum aggregates
[2] 19.0-mm nominal maximum aggregates

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

This study was conducted to prepare precision estimates for AASHTO Standard Test Method T269, "Percent air Voids in Compacted Dense and Open Asphalt Mixtures". The AMRL proficiency data analyzed in this study included the percent air voids and the maximum and bulk specific gravities of the asphalt mixtures. The AMRL data are more up to date than the data used for the current estimate of precision and reflects the various compaction test methods and recent changes to those methods. In most cases the data sets used to derive the precision estimate included well over 60 laboratories.

The precision and bias statement recommended for T 269 is provided in Appendix E. The statement has been prepared based on the pooled precisions analyzed from the percent air void data. For majority of cases, following the procedure in section 8.1 of AASHTO T269 resulted in larger precision limits than when percent air void data were used. The reason is because some of the G_{mm} and G_{mb} data that are within the tolerance of the specific gravity would result in air void values that are outside of the tolerance of air voids. Since for design and quality control of asphalt mixtures the % air voids is the controlling property, it is therefore more reasonable to set the precisions of the % air voids based on analysis of air void data.

The consistency of the computed precision estimates with the precision estimates in Section 8.3 of T 269 was investigated. The comparison indicated that there is a close agreement between the single operator precision estimates in Section 8.3 and the single operator precision estimates computed in this study. There is also a close agreement between the multilaboratory precision estimates in Section 8.3 and the multilaboratory precision estimates computed in this study using Marshall Apparatus and Superpave Gyratory Compactor data. However, the multilaboratory precision estimates computed using California Kneading and Shear Gyratory Compactor data are significantly larger than the current multilaboratory precision estimates in Section 8.3. This brings up the question of whether the data from California Kneading and Shear Gyratory Compactors have been included in the preparation of the Current T 269 precisions.

The agreement of the computed precision estimates with the precision estimates computed in Phase 1 of the NCHRP 9-26 study was also investigated. The comparison indicated that the precision estimates for % air voids of specimens compacted according to AASHTO 312 in the Proficiency Sample Program (PSP) were significantly larger than the precision estimates for relative density obtained as part of the interlaboratory study (ILS) in Phase 1 of the project. The reason for this difference is speculated to be the difference in the preparation of the samples in the two studies. The PSP samples were mixed and compacted by the participating laboratories where the ILS samples were mixed in the AMRL laboratory and compacted in various laboratories. This would result in greater variability in the % air voids of the PSP specimens than in those of ILS specimens.

4.2 RECOMMENDATIONS

The following recommendations are expected to improve the precision estimates of AASHTO T 269:

The current precision of T 269 test method depends on the precision of test methods for bulk specific and maximum specific gravities. It was shown in this study that the specific gravities that are measured to be within acceptable range of two results might result in air void values that fall outside of the acceptable range. Therefore, there is a probability of error in accepting an air void that is in fact outside of the acceptable range. Therefore, it is recommended that the precision limits for T269 to be determined based on precision of % air voids.

The precision estimates computed in this study are limited to the four compaction methods used. The field compaction was not included in the study. It is recommended to conduct an interlaboratory study to determine the precision estimates of the percent air voids of the field compacted cores.

The precision statement recommended in this study only updates the precision estimates in Section 8.3 of AASHTO T269. It is recommended to conduct an interlaboratory study to include AASHTO T275 Test Method to update the precision estimates in Section 8.2 of AASHTO T269.

AASHTO T331 “Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method” [13] has been added to AASHTO T269 for measuring the bulk specific gravity of compacted asphalt mixtures. It is recommended to conduct an interlaboratory study to determine precision estimates for T269 based on the AASHTO T331 test data.

It is recommended that the precision and bias statement in Section 4.4 to be adopted for T269. The current precision statement in T269 is blind to various compaction methods while as observed in this study the precisions resulting from various compaction methods could be quite different. Therefore, the precision estimates should be specific to each method of compaction.

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[1] Spellerberg, P.A., Savage, D.A., and Pielert, J.H., "Precision Estimates of Selected Volumetric Properties of HMA Using Non-Absorptive Aggregate," NCHRP Web Document 54, 2003.

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[4] Azari, H., Lutz, R., and Spellerberg, P., "Precision Estimates of Selected Volumetric Properties of HMA Using Absorptive Aggregate," Submitted for Approval by the NCHRP 9-26 Panel

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[7] AMRL Web Site: http://www.amrl.net

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[9] AASHTO, Designation T245, "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus" Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 25th Edition, AASHTO, Washington, DC, 2005, CD-ROM.

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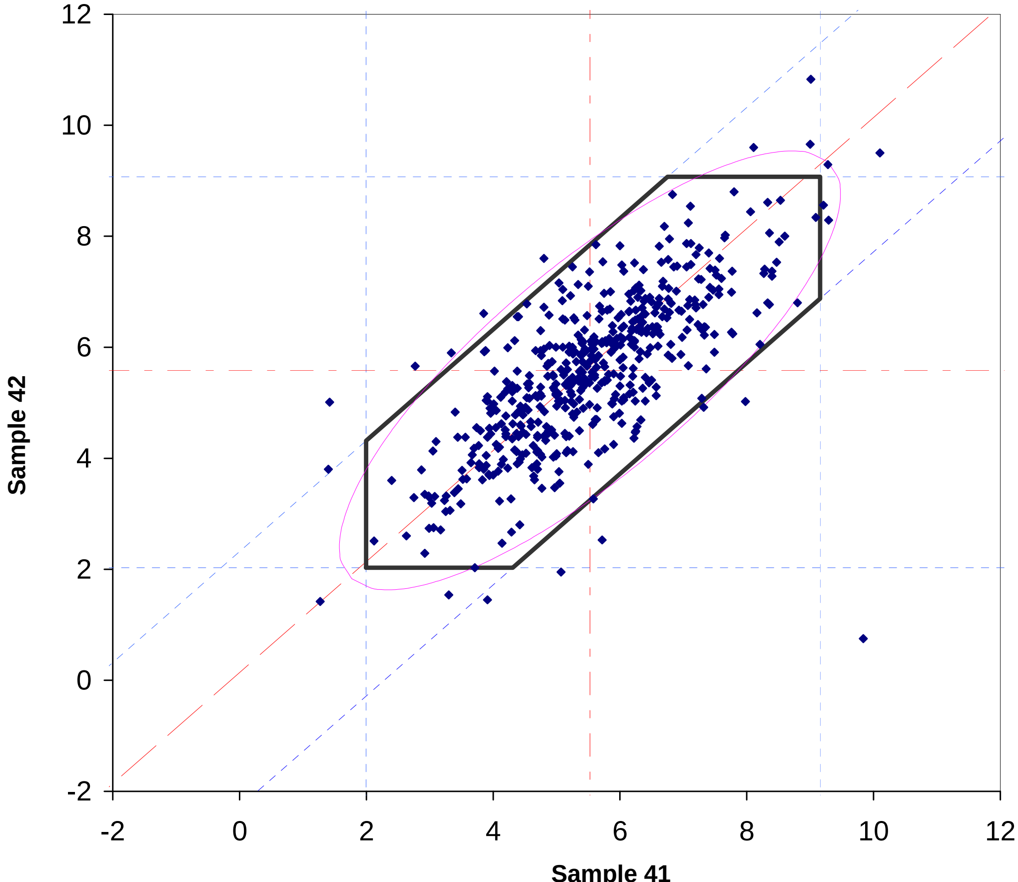
[12] Ku, Harry H., "Statistical Concepts in Metrology," NIST Special Publication 300, Volume 1, 1969: p 316-40.

[13] AASHTO, Designation T331, "Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method," Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 27th Edition, AASHTO, Washington, DC, 2007, CD-ROM.

APPENDIX A: MARSHALL COMPACTION METHOD

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 41 and 42
Percent Air Voids Using the Marshall Apparatus in T245



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 41 and 42
Final Report Issued: August 12, 2004

Participation:

532	Total Laboratories
3	Laboratories Determined to be Invalid
21	Laboratories Determined to be Outliers
508	Total Laboratorires Included in Analysis

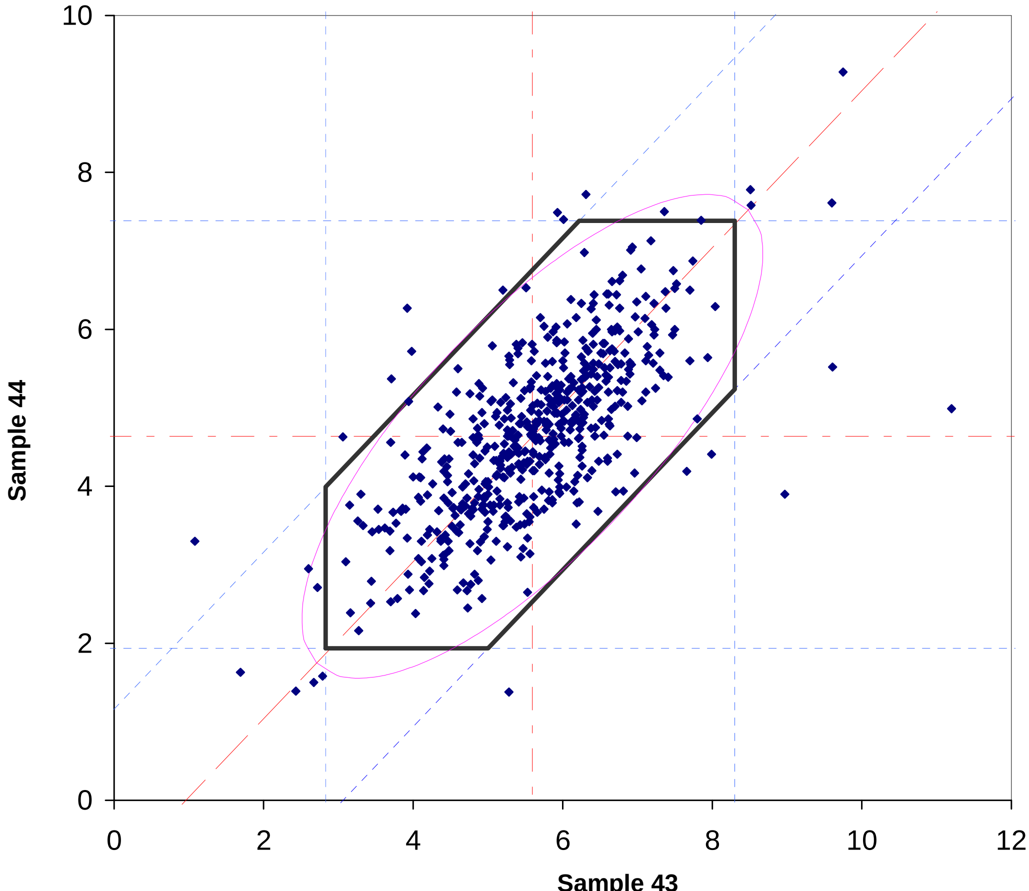
Average Results	
Sample 41 Average	Sample 42 Average
5.53	5.58

Repeatability			
1s	d2s	CV% (Sample 41)	CV% (Sample 42)
0.58	1.65	10.5	10.4

Reproducibility (Sample 41)		
1s	d2s	CV%
1.24	3.52	22.5

Reproducibility (Sample 42)		
1s	d2s	CV%
1.26	3.57	22.6

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 43 and 44
Percent Air Voids Using the Marshall Apparatus in T245



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 43 and 44
Final Report Issued: August 16, 2005

Participation:

561	Total Laboratories
32	Laboratories Determined to be Invalid
23	Laboratories Determined to be Outliers
506	Total Laboratorires Included in Analysis

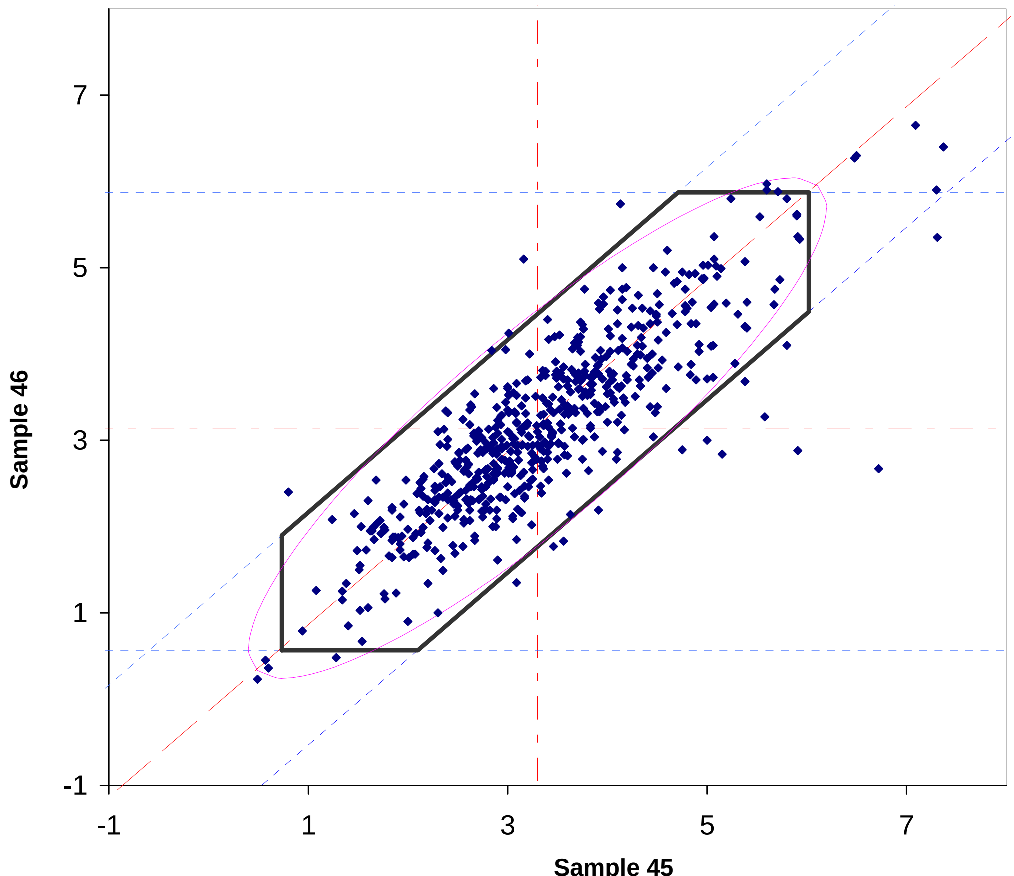
Average Results	
Sample 43 Average	Sample 44 Average
5.59	4.64

Repeatability			
1s	d2s	CV% (Sample 43)	CV% (Sample 44)
0.51	1.44	9.1	11.0

Reproducibility (Sample 43)		
1s	d2s	CV%
0.96	2.71	17.1

Reproducibility (Sample 44)		
1s	d2s	CV%
0.97	2.73	20.8

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 45 and 46
Percent Air Voids Using the Marshall Apparatus in T245



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 45 and 46
Final Report Issued: August 17, 2006

Participation:

609	Total Laboratories
3	Laboratories Determined to be Invalid
28	Laboratories Determined to be Outliers
578	Total Laboratorires Included in Analysis

Average Results	
Sample 45 Average	Sample 46 Average
3.30	3.14

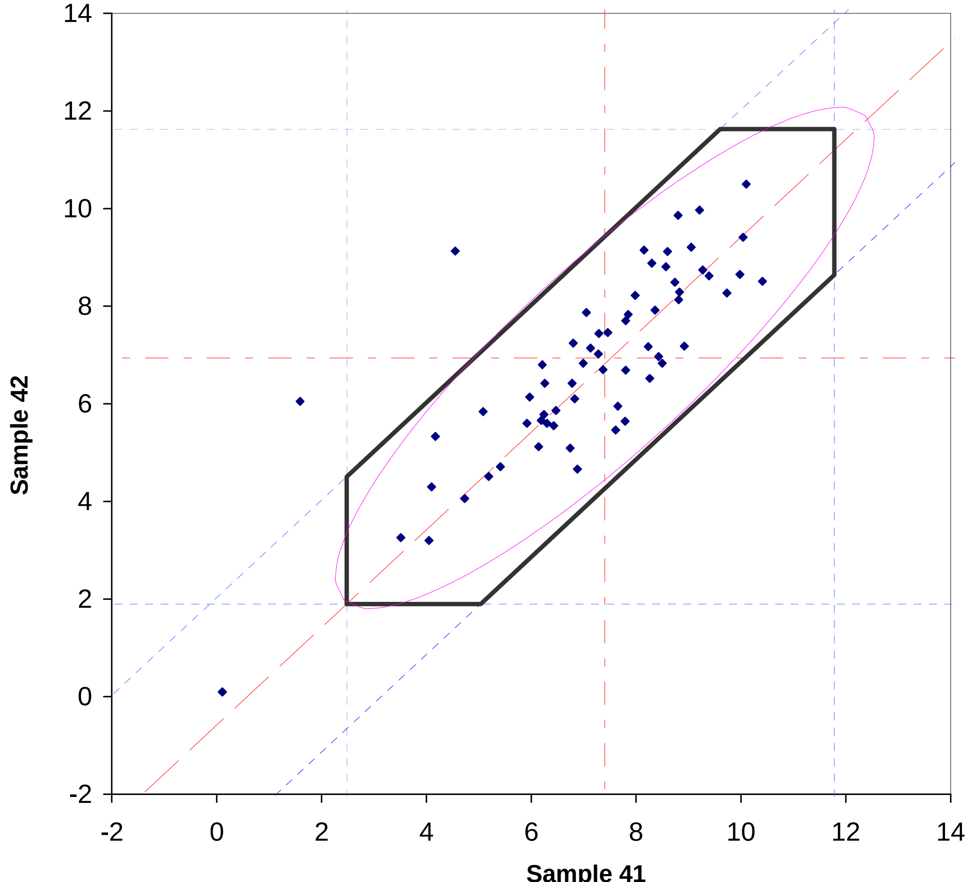
Repeatability			
1s	d2s	CV% (Sample 45)	CV% (Sample 46)
0.33	0.94	10.1	10.6

Reproducibility (Sample 45)		
1s	d2s	CV%
0.94	2.67	28.6

Reproducibility (Sample 46)		
1s	d2s	CV%
0.93	2.63	29.6

APPENDIX B: CALIFORNIA KNEADING COMPACTION METHOD

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 41 and 42
Percent Air Voids Using the California Kneading Compactor- T247



Graph Legend
Lines With Small Dash Marks - Sample Outlier
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 41 and 42
Final Report Issued: August 16, 2004

Participation:

64	Total Laboratories
2	Laboratories Determined to be Invalid
2	Laboratories Determined to be Outliers
60	Total Laboratorires Included in Analysis

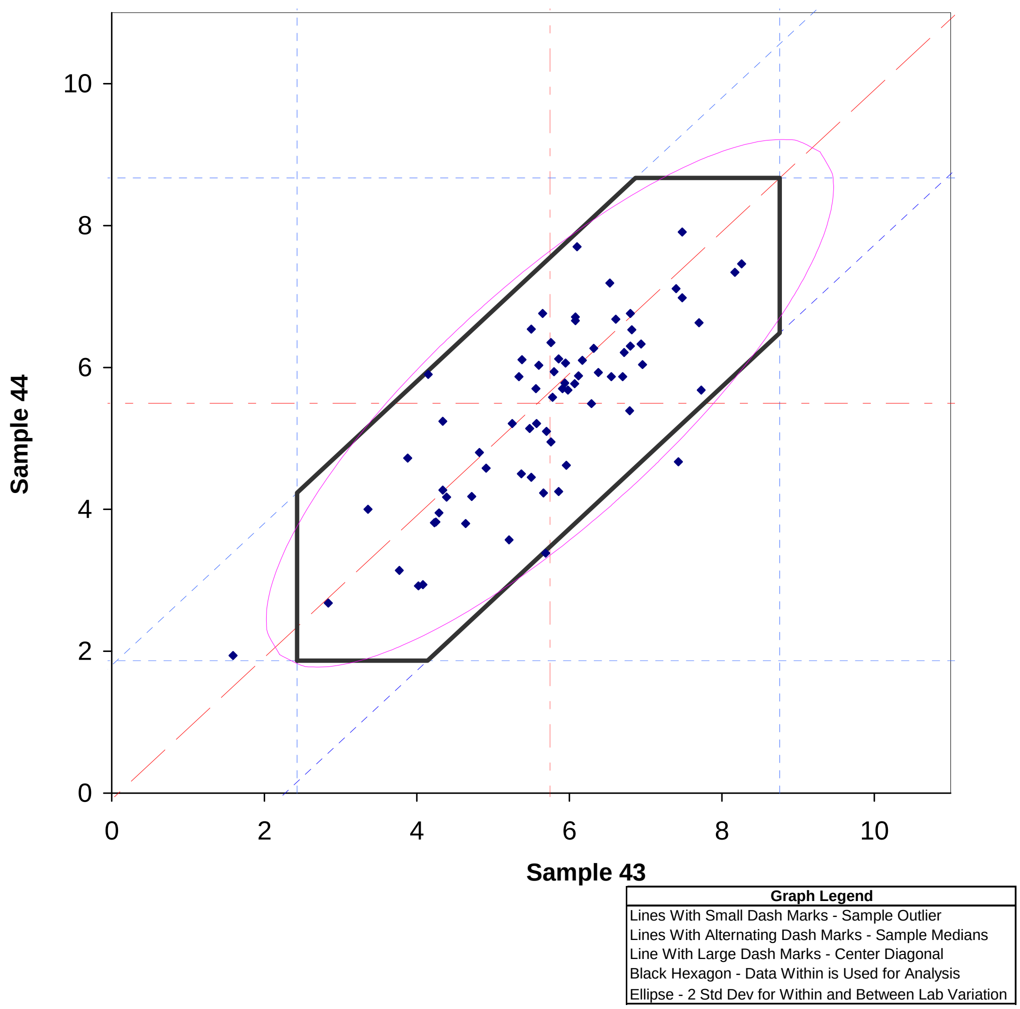
Average Results	
Sample 41 Average	Sample 42 Average
7.40	6.94

Repeatability			
1s	d2s	CV% (Sample 41)	CV% (Sample 42)
0.61	1.72	8.2	8.8

Reproducibility (Sample 41)		
1s	d2s	CV%
1.62	4.58	21.86

Reproducibility (Sample 42)		
1s	d2s	CV%
1.69	4.8	24.4

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 43 and 44
Percent Air Voids Using the California Kneading Compactor- T247



Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 43 and 44
Final Report Issued: August 16, 2005

Participation:

72	Total Laboratories
0	Laboratories Determined to be Invalid
3	Laboratories Determined to be Outliers
69	Total Laboratorires Included in Analysis

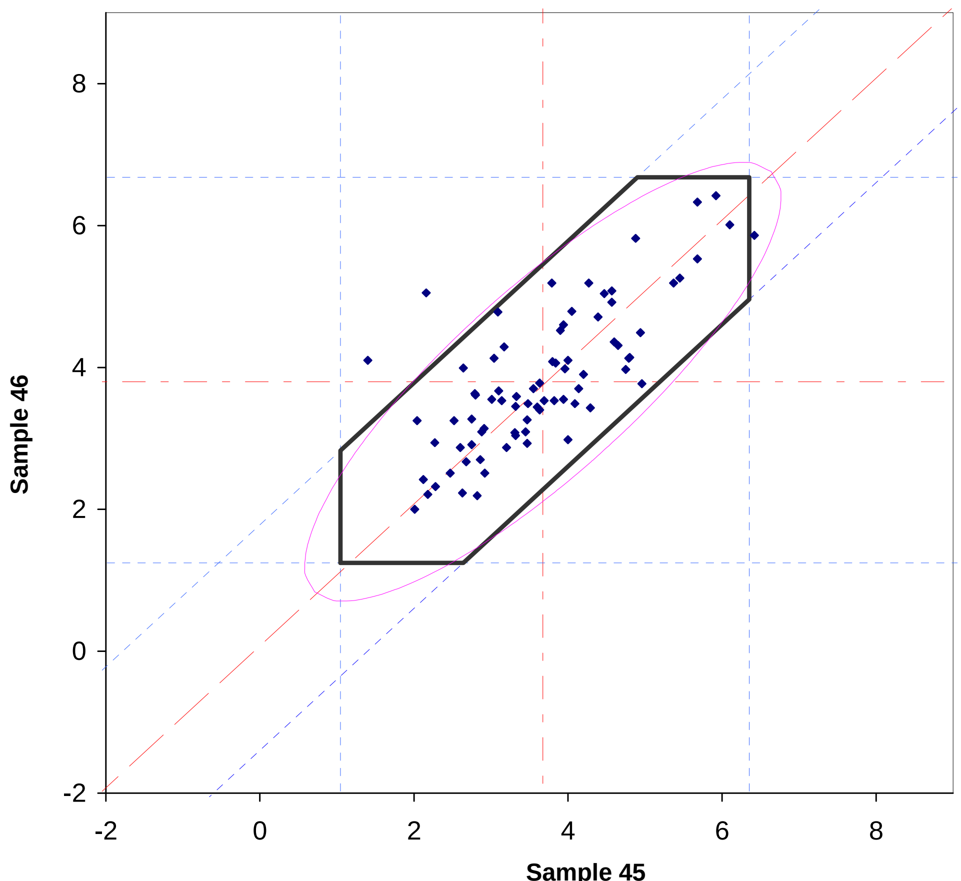
Average Results	
Sample 43 Average	Sample 44 Average
5.75	5.50

Repeatability			
1s	d2s	CV% (Sample 43)	CV% (Sample 44)
0.53	1.50	9.2	9.7

Reproducibility (Sample 43)		
1s	d2s	CV%
1.15	3.24	19.95

Reproducibility (Sample 44)		
1s	d2s	CV%
1.22	3.4	22.1

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 45 and 46
Percent Air Voids Using the California Kneading Compactor- T247



Graph Legend
Lines With Small Dash Marks - Sample Outlier
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Design Samples 45 and 46
Final Report Issued: August 17, 2006

Participation:

78	Total Laboratories
0	Laboratories Determined to be Invalid
3	Laboratories Determined to be Outliers
75	Total Laboratorires Included in Analysis

Average Results	
Sample 45 Average	Sample 46 Average
3.67	3.80

Repeatability			
1s	d2s	CV% (Sample 45)	CV% (Sample 46)
0.41	1.17	11.3	10.9

Reproducability (Sample 45)		
1s	d2s	CV%
0.98	2.76	26.58

Reproducability (Sample 46)		
1s	d2s	CV%
1.00	2.8	26.3

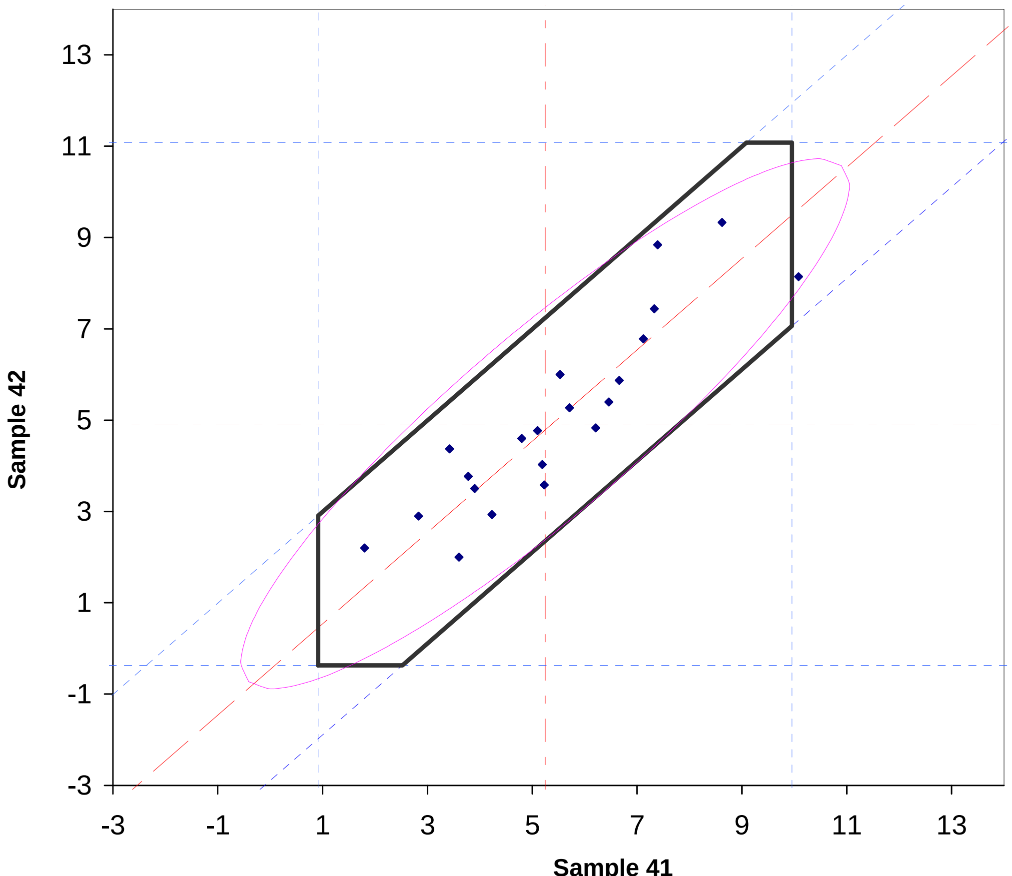
APPENDIX C: GYRATORY SHEAR COMPACTION METHOD

Graph and Analysis Results for AASHTO T269

Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AMRL Hot-Mix Asphalt Design Samples 41 and 42

Percent Air Voids Using the Gyratory Shear Compactor in D4013



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Sample Type: Samples 41 and 42
Final Report Issued: August 12, 2004

Participation:

21	Total Laboratories
0	Laboratories Determined to be Invalid
1	Laboratories Determined to be Outliers
20	Total Laboratorires Included in Analysis

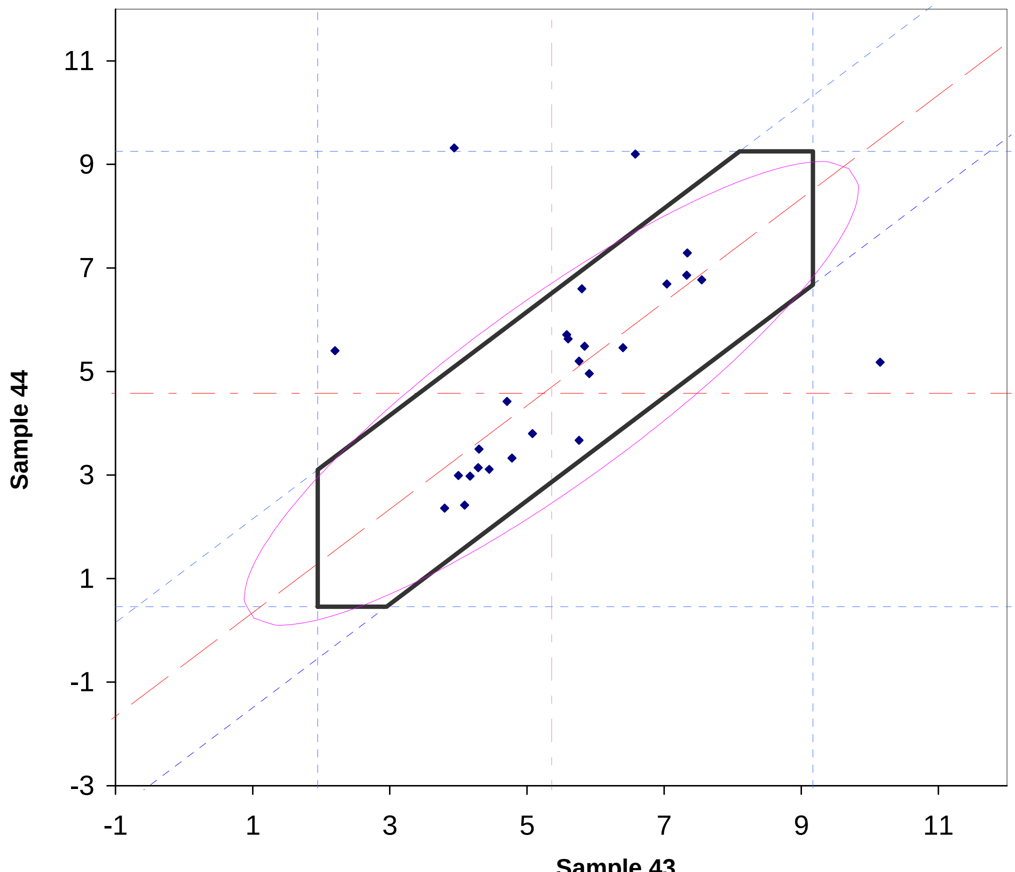
Average Results	
Sample 41 Average	Sample 42 Average
5.25	4.92

Repeatability			
1s	d2s	CV% (Sample 41)	CV% (Sample 42)
0.62	1.74	11.7	12.5

Reproducability (Sample 41)		
1s	d2s	CV%
1.74	4.92	33.17

Reproducability (Sample 42)		
1s	d2s	CV%
2.02	5.71	41.0

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 43 and 44
Percent Air Voids Using the Gyratory Shear Compactor in D4013



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Sample Type: Samples 43 and 44
Final Report Issued: August 16, 2005

Participation:

26	Total Laboratories
7	Laboratories Determined to be Invalid
1	Laboratories Determined to be Outliers
18	Total Laboratorires Included in Analysis

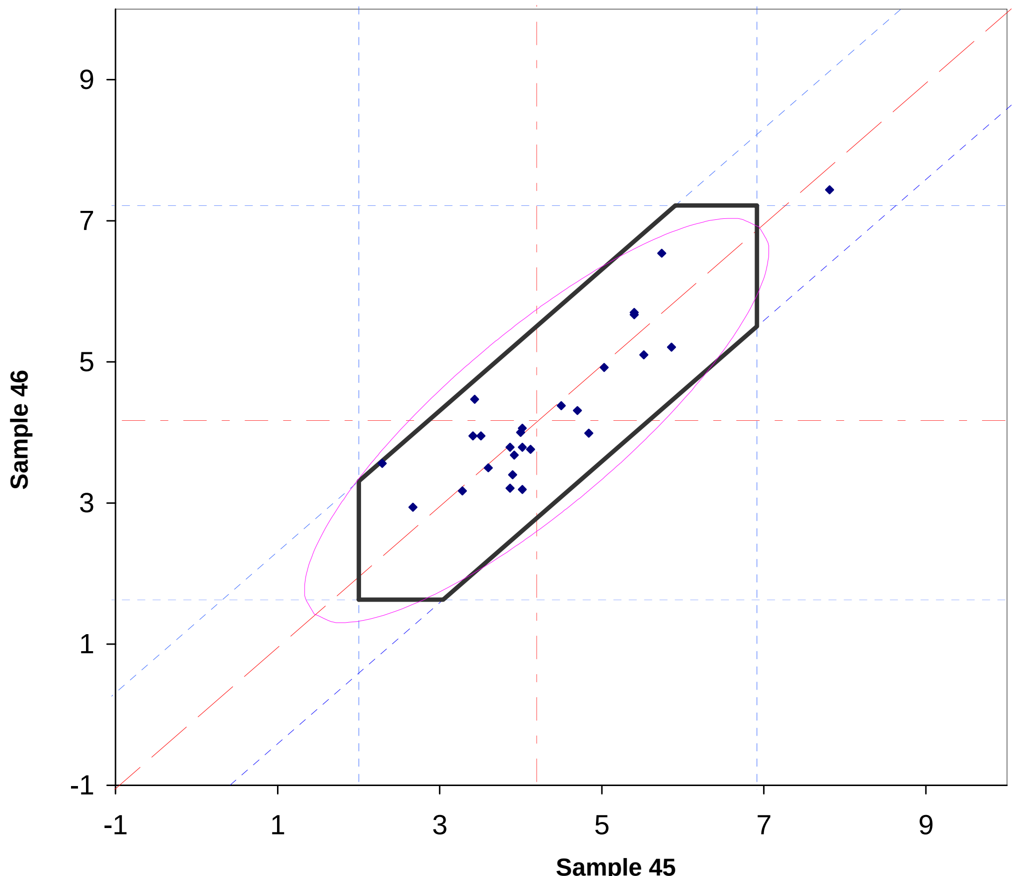
Average Results	
Sample 43 Average	Sample 44 Average
5.36	4.58

Repeatability			
1s	d2s	CV% (Sample 43)	CV% (Sample 44)
0.52	1.46	9.6	11.3

Reproducability (Sample 43)		
1s	d2s	CV%
1.21	3.42	22.54

Reproducability (Sample 44)		
1s	d2s	CV%
1.65	4.67	36.1

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Design Samples 45 and 46
Percent Air Voids Using the Gyratory Shear Compactor in D4013



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Sample Type: Samples 45 and 46
Final Report Issued: December 13, 2006

Participation:

26	Total Laboratories
0	Laboratories Determined to be Invalid
1	Laboratories Determined to be Outliers
25	Total Laboratorires Included in Analysis

Average Results	
Sample 45 Average	Sample 46 Average
4.20	4.17

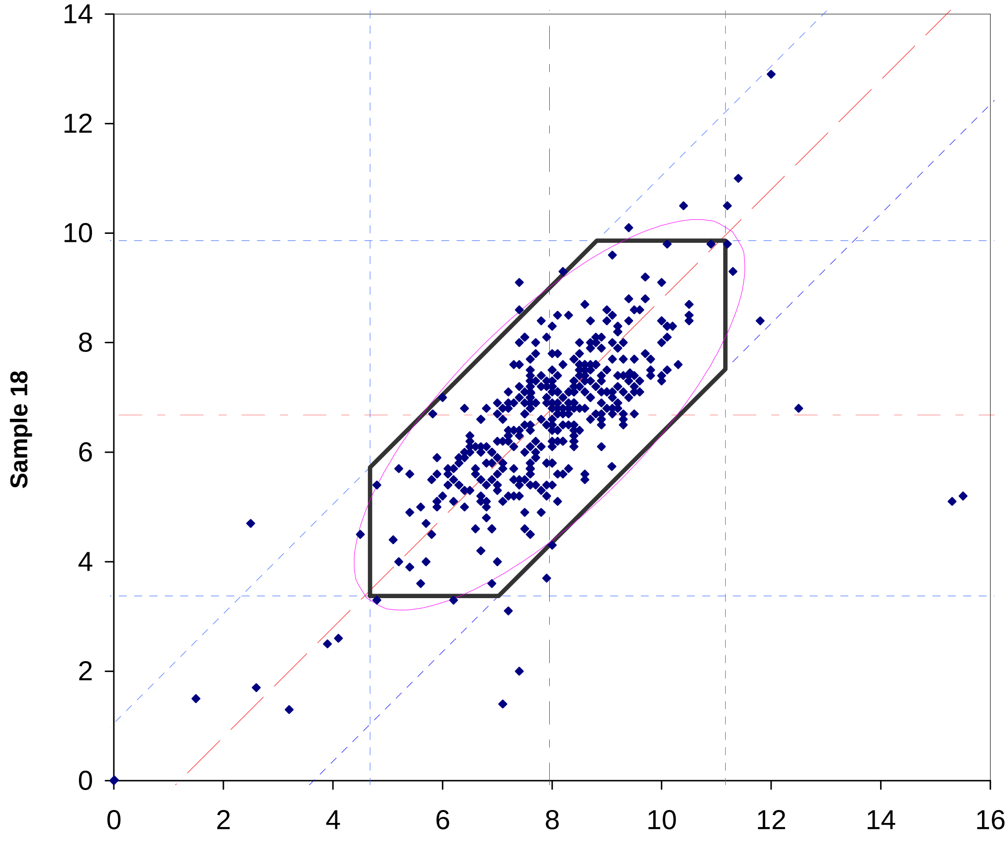
Repeatability			
1s	d2s	CV% (Sample 45)	CV% (Sample 46)
0.39	1.09	9.2	9.3

Reproducability (Sample 45)		
1s	d2s	CV%
0.93	2.62	22.08

Reproducability (Sample 46)		
1s	d2s	CV%
0.90	2.55	21.6

APPENDIX D: SUPERPAVE GYRATORY COMPACTION METHOD

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Gyratory Samples 17 and 18
Percent Air Voids Using the Superpave Gyratory Compactor in T312



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Gyratory Samples 17 and 18
Final Report Issued: September 2, 2004

Participation:

392	Total Laboratories
12	Laboratories Determined to be Invalid
22	Laboratories Determined to be Outliers
358	Total Laboratorires Included in Analysis

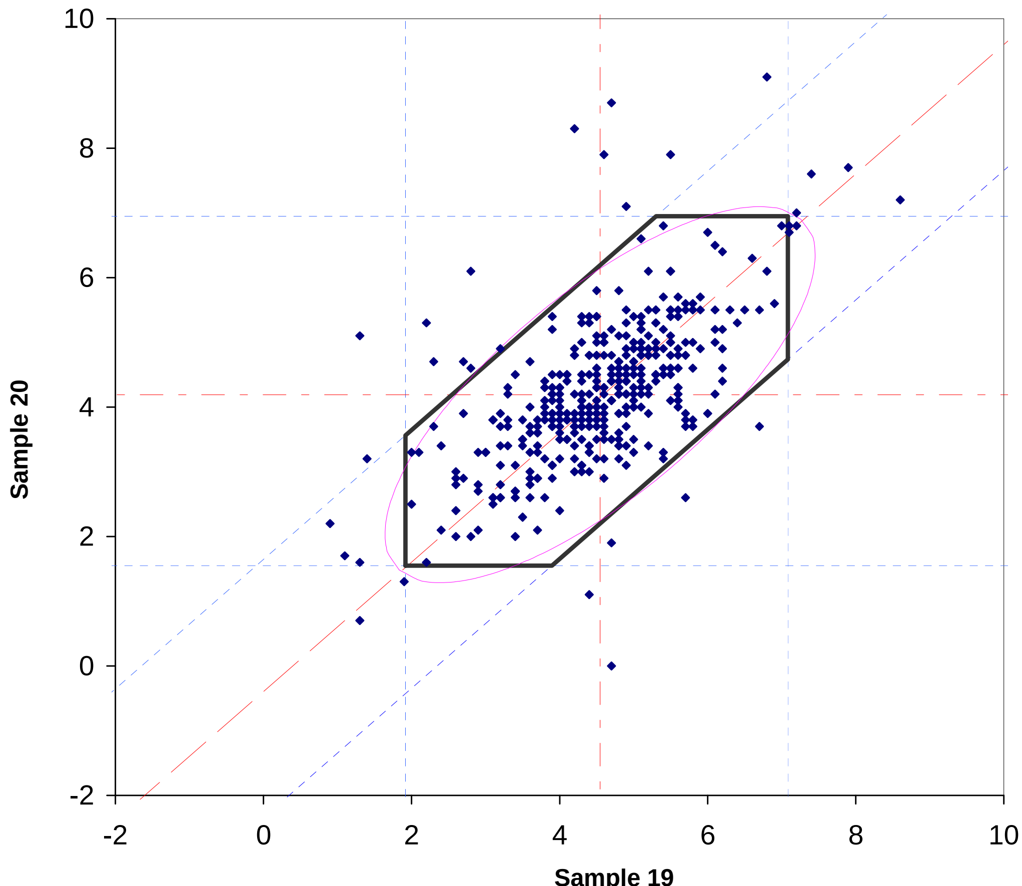
Average Results	
Sample 17 Average	Sample 18 Average
7.95	6.68

Repeatability			
1s	d2s	CV% (Sample 17)	CV% (Sample 18)
0.59	1.66	7.4	8.8

Reproducibility (Sample 17)		
1s	d2s	CV%
1.13	3.19	14.2

Reproducibility (Sample 18)		
1s	d2s	CV%
1.10	3.11	16.4

Graph and Analysis Results for AASHTO T269
Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
AMRL Hot-Mix Asphalt Gyratory Samples 19 and 20
Percent Air voids Using the Superpave Gyratory Compactor in T312



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Hot-Mix Asphalt Gyratory Samples 19 and 20
Final Report Issued: September 1, 2005

Participation:

434	Total Laboratories
12	Laboratories Determined to be Invalid
26	Laboratories Determined to be Outliers
396	Total Laboratorires Included in Analysis

Average Results	
Sample 19 Average	Sample 20 Average
4.55	4.19

Repeatability			
1s	d2s	CV% (Sample 19)	CV% (Sample 20)
0.49	1.39	10.8	11.7

Reproducibility (Sample 19)		
1s	d2s	CV%
0.90	2.55	19.8

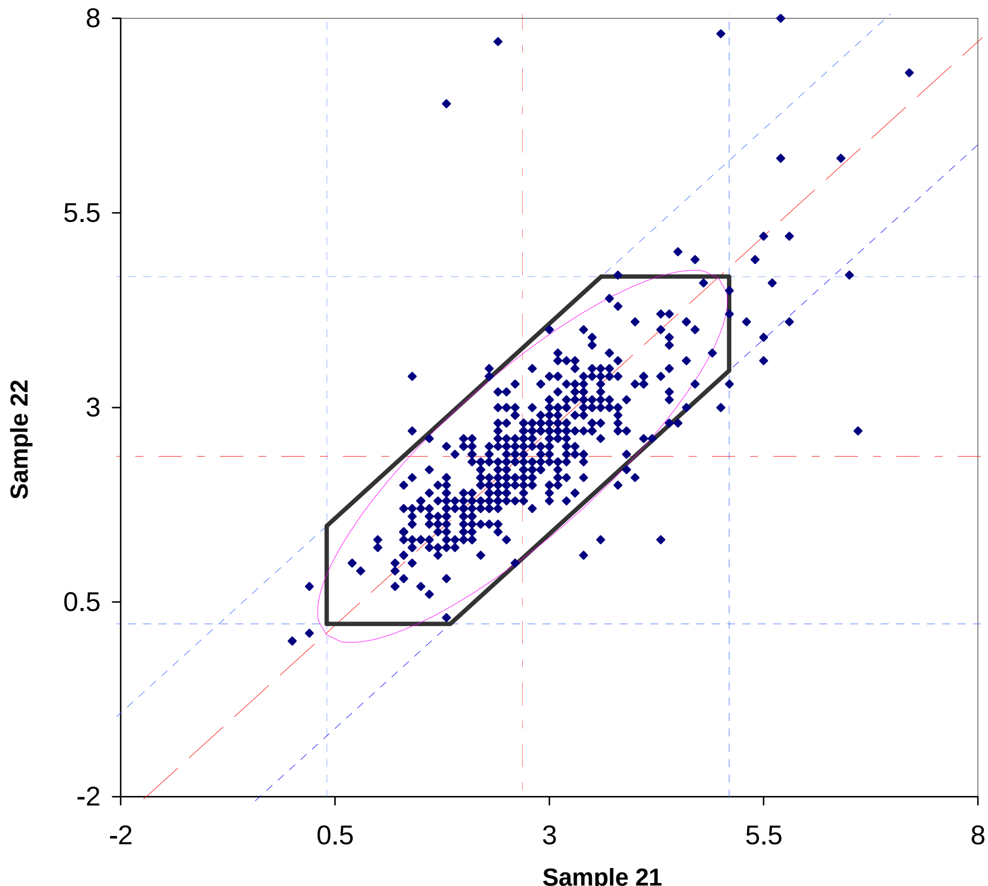
Reproducibility (Sample 20)		
1s	d2s	CV%
0.91	2.56	21.6

Graph and Analysis Results for AASHTO T269

Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AMRL Hot-Mix Asphalt Design Samples 21 and 22

Percent Air Voids Using the Superpave Gyratory Compactor in T312



Graph Legend
Lines With Small Dash Marks - Sample Outlier Boundaries
Lines With Alternating Dash Marks - Sample Medians
Line With Large Dash Marks - Center Diagonal
Black Hexagon - Data Within is Used for Analysis
Ellipse - 2 Std Dev for Within and Between Lab Variation

Source of Data: AASHTO Materials Reference Laboratory Proficiency Sample Program
AMRL Sample Type: Samples 21 and 22
Final Report Issued: August 28, 2006

Participation:

480	Total Laboratories
11	Laboratories Determined to be Invalid
33	Laboratories Determined to be Outliers
436	Total Laboratorires Included in Analysis

Average Results	
Sample 21 Average	Sample 22 Average
2.69	2.37

Repeatability			
1s	d2s	CV% (Sample 21)	CV% (Sample 22)
0.32	0.92	12.0	13.6

Reproducability (Sample 21)		
1s	d2s	CV%
0.79	2.22	29.2

Reproducability (Sample 22)		
1s	d2s	CV%
0.74	2.09	31.2

APPENDIX E: PRECISION STATEMENT FOR AASHTO T269

PRECISION STATEMENT FOR AASHTO T269 PERCENT AIR VOIDS IN COMPACTED DENSE AND OPEN ASPHALT MIXTRURES

X. Precision and Bias

X.1 Precision

Criteria for judging the acceptability of percent air voids test results that are obtained using T 166 and T 209 for dense asphalt mixtures using nonporous aggregates are:

X.1.1 Single-Operator Precision (Repeatability) – The figures in Column 3 of Table X are the standard deviations that have been found to be appropriate for the compaction method described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table X, Column 4.

X.1.2 Multilaboratory Precision (Reproducibility) – The figures in Column 3 of Table X are the standard deviations that have been found to be appropriate for the compaction method described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table X, Column 4.

Table X – Precision Estimates

Compaction Method	Specimen Diameter	Standard Deviation (1s)[a]	Acceptable Range of Two Test Results (d2s)[a]
Single Operator Precision:			
AASHTO T245[b]	4-inch	0.48	1.36
AASHTO T247	4-inch	0.52	1.47
ASTM D4013	4-inch	0.50	1.42
AASHTO T312	6-inch	0.47	1.33
Multilaboratory Precision:			
AASHTO T245[b]	4-inch	1.08	3.06
AASHTO T247	4-inch	1.39	3.94
ASTM D4013	4-inch	1.49	4.22
AASHTO T312	6-inch	1.01	2.86

[a] These values represent the 1s and d2s limits described in ASTM Practice C670.

[b] The results reported for specimens compacted using T245 were determined as the average of three specimens.

Note – The precision estimates given in Table X are based on the analysis of test results from three pairs of AMRL proficiency samples. The data analyzed consisted of results from 20 to 578 laboratories for each of the three pairs of samples. The analysis included three binder grades: PG 70-22, PG 64-10, PG 64-22. Average results for air voids ranged from 2.37% to 7.95%. The details of this analysis are in NCHRP Final Report, NCHRP Project No. 9-26, Phase 5.

X.2 Bias – No information can be presented on the bias of the procedure because no material having an accepted reference value is available.