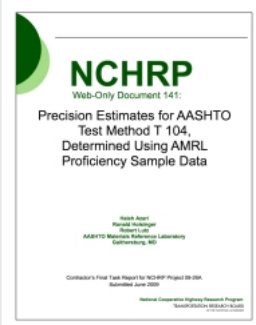

Precision Estimates for AASHTO Test Method T 104, Determined Using AMRL Proficiency Sample Data

DETAILS

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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 various highway construction materials. 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 and part two investigates the effect of laboratory conditioning time on the volumetric properties of mixtures with absorptive aggregates [4]. The report from Phase 5 includes update of precision estimates for AASHTO Standard Test Method T 269 [5].

This report includes the results of Part 1 of 3 in Task 1 of NCHRP 9-26A where data from the AMRL Proficiency Sample Program (PSP) are used to update precision estimates for AASHTO Standard Test Method T 104 “Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate” [6].

The data used in this study are from the sulfate soundness properties of coarse and fine aggregates that were sent to the laboratories participating in the AMRL Proficiency Program. The laboratories receive annual or biannual shipments of AMRL paired proficiency samples, which are tested according to specified AASHTO test methods [7, 8]. The soundness properties that were tested and are reported in this report include percent loss of aggregates subjected to saturated solutions of sodium sulfate and magnesium sulfate. The materials that were tested include coarse aggregates passing 19-mm sieves and fine aggregates passing 2.36-mm sieves.

The technique developed by AMRL in Phase 3 of NCHRP 9-26 project 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.

The precision statement for the standard method of test for soundness of aggregates using sodium sulfate and magnesium sulfate in this study resulted from analysis of 60 paired data sets from tests on 12 shipments of AMRL paired proficiency samples. Only the most recent proficiency samples were used in order to account for changes in test precision resulting from recent improvements in the test method.

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. Some test methods need to be expanded to take into account a wider range of materials while other newer test methods may not have precision estimates of any kind.

The values in the precision statement of AASHTO T104-99 (2003) are based on testing according to the method prior to revision in 1991. The precisions need to be reevaluated to reflect the 1991 revisions to the method. Furthermore, the precision and bias statement does not include precision estimates for sulfate soundness measurement of fine aggregates. The statement need to be expanded to include precision estimates for testing fine aggregate.

1.1.2 Research Objective

The objective of this study as Part 1 of 3 in Task 1 of NCHRP 9-26a study is to update and expand single-operator and multilaboratory precision estimates for the AASHTO T104, "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate" using the most recent sets of AMRL proficiency sulfate soundness data. This is to reflect the revisions that were made to the test method in 1991 and to include precision for testing fine aggregate.

1.2 SCOPE OF STUDY

This work is limited to an evaluation of data collected from laboratories participating in the sulfate soundness testing of coarse and fine aggregates according to AASHTO T 104 for the AMRL Proficiency Sample Program (PSP). The test data are the percentages of aggregate loss subjected to saturated solutions of sodium sulfate or magnesium sulfate. The resulting precision estimates will reflect the range of test values included in the scope of the AMRL Proficiency Sample Program.

1.3 PROFICIENCY SAMPLES USED IN STUDY

Included in the study are the most recent AMRL proficiency samples that were tested according to AASHTO T 104 "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate." Table 1-1 and Table 1-2 provide the sample designations of the AMRL proficiency coarse and fine aggregate samples and the date of the final reports on the analysis of the sample properties.

Table 1-1- Sample Designation and Date of Report for Soundness Test on Coarse Aggregate

Sample Designation	Date of Final Report
141 & 142	November 2003
145 & 146	November 2004
149 & 150	November 2005
153 & 154	November 2006
157 & 158	November 2007
161 & 162	November 2008

Table 1-2- Sample Designation and Date of Report for Soundness Test on Fine Aggregate

Sample Designation	Date of Final Report
143 & 144	May 2004
147 & 148	May 2005
151 & 152	April 2006
155 & 156	March 2007
159 & 160	March 2008
163 & 164	March 2009

CHAPTER 2. RESULTS OF ANALYSIS AND ESTIMATES OF PRECISION

2.1 TEST DATA

The data used in this study are from sieve analysis and sulfate soundness test on coarse and fine aggregates. For the coarse aggregate, the sieve analysis data includes total percent passing of 19.0, 12.5, 9.5, and 4.75-mm sieves. The soundness test data include percent loss on two size fractions: 19.0 mm to 9.5mm passing 8.0-mm sieve and 9.5mm to 4.75mm passing 4.0-mm sieve. For the fine aggregate, the sieve analysis results include total percent passing of 2.36- mm, 1.18-mm, 600-micron, and 300-micron sieves. The results of soundness test include percent loss on three size fractions: finer than the 1.18-mm, 600-micron, and 300-micron sieves. The soundness test were performed by five repeated immersion of fine and coarse aggregates in saturated solutions of sodium sulfate, magnesium sulfate, or both. For each size fraction, each laboratory was requested to report the amount of materials finer than the designated sieve as a percentage of the original mass of the fraction to the nearest 0.01 percent.

2.2 ANALYSIS OF THE DATA

The precision estimates for T 104 are based on the weighted average percent soundness loss. As explained in Section 8 of AASHTO T 104, the weighted percent loss is calculated from the percentage loss of each size fraction and from the average grading of the aggregates. This chapter provides the statistics of the sieve analysis, sulfate soundness loss of each size fraction, the weighted average sulfate soundness loss, and the computed precision estimates for sodium and magnesium sulfate loss of coarse and fine aggregate.

2.2.1 Coarse Aggregate Sulfate Soundness Percentage Loss

2.2.1.1 Sieve Analysis Results of Coarse Aggregate

A summary of the results of sieve analysis of the 6 pairs of PSP coarse aggregate are summarized in Table 2-1. The percent passing of 19.0 mm, 9.5 mm, and 4.75 mm sieves were used to compute percent retained on 9.5-mm and 4.75-mm sieves for computing the weighted loss of coarse aggregates.

Table 2-1- Summary Table for Sieve Analysis of Coarse Aggregate: Percent Material Passing

Sample Number	Average No. of Labs	19.5 mm	12.5 mm	9.5 mm	4.75 mm
141 & 142	977	87.27	50.13	17.02	0.64
145 & 146	1055	87.58	50.85	17.58	0.79
149 & 150	1101	86.81	47.21	12.36	1.10
153 & 154	1067	89.99	52.22	21.13	1.40
157 & 158	1139	88.94	50.13	14.90	0.72
161 & 162	1217	99.98	60.45	23.49	3.46

2.2.1.2 Coarse Aggregate Percentage Loss by Sodium Sulfate

Fraction Passing 8.0-mm Sieve

The sodium sulfate-percentage losses of 19.0-mm to 9.5-mm aggregate fraction passing 8.0-mm sieve were analyzed for 6 pairs of proficiency samples. Table 2-2 displays a summary of the results of the analysis. The plots of the sodium sulfate percent loss data of 19.0-mm to 9.5-mm aggregate fraction passing 8.0 mm sieve for the 6 pairs of proficiency samples are found in Appendix A.

Table 2-2- Summary Table for Sodium Sulfate-Percentage Loss of 19.0-mm to 9.5-mm Fraction Passing 8.0-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	215	0.26	0.26	0.084	32.5	32.5	0.164	63.7	0.150	58.2
145 & 146	239	0.87	0.89	0.260	30.0	29.4	0.722	83.3	0.726	81.9
149 & 150	284	0.70	0.65	0.198	28.5	30.4	0.424	61.0	0.385	59.2
153 & 154	272	3.16	3.14	0.677	21.4	21.6	2.819	89.1	2.816	89.6
157 & 158	273	0.29	0.29	0.071	24.2	24.1	0.182	62.4	0.183	62.4
161 & 162	321	3.12	2.98	0.559	17.9	18.8	2.385	76.4	2.267	76.2

Fraction Passing 4.0-mm Sieve

The sodium sulfate-percentage losses of 9.5-mm to 4.75-mm aggregate fraction passing 4.0-mm sieve were analyzed for 6 pairs of proficiency samples. Table 2-3 displays a summary of the results of the analysis. The plots of the sodium sulfate percent loss data of 9.5-mm to 4.75-mm aggregate fraction passing 4.0 mm sieve for the 6 pairs of proficiency samples are found in Appendix B.

Table 2-3- Summary Table for Sodium Sulfate-Percentage Loss of 9.0-mm to 4.75-mm of Fraction Passing 4.0-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	225	0.46	0.46	0.120	26.1	25.8	0.261	56.8	0.271	58.4
145 & 146	239	0.87	0.77	0.193	22.2	25.1	0.630	72.4	0.588	76.2
149 & 150	277	1.03	1.01	0.241	23.5	24.0	0.595	58.0	0.616	61.3
153 & 154	263	2.64	2.58	0.517	19.6	20.1	2.497	94.7	2.465	95.7
157 & 158	276	0.44	0.47	0.089	20.2	18.7	0.288	65.8	0.317	66.7
161 & 162	323	4.61	4.66	0.652	14.2	14.0	3.415	74.2	3.406	73.1

Weighted Average Sodium Sulfate Loss of Coarse Aggregates

The weighted average sodium sulfate loss of coarse aggregates was computed from the sodium sulfate losses of 19.0-mm to 9.5-mm aggregate fraction passing 8.0-mm sieve, the sodium sulfate losses of 9.5-mm to 4.75-mm aggregate fraction passing 4.0-mm sieve, and the original percent retained on 12.5-mm, 9.5-mm, and 4.75-mm sieves (from Table 2-1). The computation was performed according to Eq.1:

$$\text{Weighted Loss} = \frac{L_8 * R_{12.5} + L_8 * R_{9.5} + L_4 * R_{4.75}}{R_{12.5} + R_{9.5} + R_{4.75}} \qquad \text{(Eq. 1)}$$

L_8 = % loss on 8-mm sieve

L_4 = % loss on 4-mm sieve

$R_{12.5}$ = % retained on 12.5-mm sieve

$R_{9.5}$= % retained on 9.5-mm sieve

$R_{4.75}$= % retained on 4.75-mm sieve

The computed weighted average sodium sulfate losses of the 6 pairs of proficiency sample coarse aggregates were analyzed to determine the precision estimates for T 104. Table 2-4 displays the results of the analyses. A review of the data shown in Table 2-4 indicates that there is a trend between the average and standard deviation of the percent soundness loss; therefore, the form of the precision estimates should be based on the sample coefficient of variation. The average repeatability sample coefficient of variation for the 6 pairs of samples analyzed is 18.7 percent. The corresponding average reproducibility sample coefficient of variation is 67.7 percent. The plots of the weighted average sodium sulfate percent loss of coarse aggregates for the 6 pairs of proficiency samples are found in Appendix C.

Table 2-4- Summary Table for Sodium Sulfate-Weighted Average Percentage Loss of Coarse Aggregate

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	213	0.30	0.30	0.070	23.4	23.8	0.161	53.5	0.147	49.8
145 & 146	233	0.87	0.86	0.206	23.8	24.0	0.673	77.8	0.667	77.8
149 & 150	281	0.75	0.70	0.176	23.6	25.0	0.424	56.8	0.397	56.5
153 & 154	267	3.07	3.03	0.522	17.0	17.2	2.728	89.0	2.710	89.4
157 & 158	221	0.29	0.32	0.026	8.8	8.1	0.2	59.4	0.185	57.9
161 & 162	323	3.45	3.37	0.512	14.8	15.2	2.5	72.4	2.429	72.2

2.2.1.3 Coarse Aggregate Percentage Loss by Magnesium Sulfate

Fraction Passing 8.0-mm Sieve

The magnesium sulfate-percentage losses of 19.0-mm to 9.5-mm aggregate fraction passing 8.0-mm sieve were analyzed for 6 pairs of proficiency samples. Table 2-5 displays the results of the analyses. The plots of the magnesium sulfate percent loss data of 19.0-mm to 9.5-mm aggregate fraction passing 8.0 mm sieve for the 6 pairs of proficiency samples are found in Appendix D.

Table 2-5- Summary Table for Magnesium Sulfate-Percentage Loss of 19.0 to 9.5-mm of Fraction Passing 8.0-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	109	0.37	0.37	0.106	28.6	28.6	0.179	48.23	0.190	51.37
145 & 146	109	0.97	0.95	0.190	19.5	20.0	0.667	68.6	0.671	70.6
149 & 150	121	1.50	1.40	0.346	23.1	24.7	0.873	58.3	0.832	59.6
153 & 154	144	14.36	14.58	1.820	12.7	12.5	9.380	65.3	9.231	63.3
157 & 158	133	0.39	0.40	0.077	19.7	19.2	0.229	58.3	0.245	60.9
161 & 162	139	11.09	10.91	1.653	14.9	15.2	7.814	70.4	7.801	71.5

Fraction Passing 4.0-mm Sieve

The magnesium sulfate-percentage losses of 9.5-mm to 4.75-mm aggregate fraction passing 4.0-mm sieve were analyzed for 6 pairs of proficiency samples. Table 2-6 displays the results of the analyses. The plots of magnesium sulfate percent loss data of 9.5-mm to 4.75-mm aggregate fraction passing 4.0 mm sieve for the 6 pairs of the proficiency samples are found in Appendix E.

Table 2-6- Summary Table for Magnesium Sulfate-Percentage Loss of 9.0 to 4.75-mm of Fraction Passing 4.0-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	113	0.67	0.72	0.158	23.7	22.0	0.376	56.5	0.420	58.5
145 & 146	121	1.85	1.71	0.401	21.7	23.4	1.352	73.1	1.328	77.5
149 & 150	118	2.67	2.71	0.386	14.4	14.2	1.719	64.3	1.760	64.9
153 & 154	134	15.20	15.48	1.475	9.7	9.5	10.381	68.3	10.674	69.0
157 & 158	145	0.77	0.80	0.196	25.5	24.5	0.496	64.5	0.507	63.3
161 & 162	140	17.97	18.17	1.745	9.7	9.6	12.447	69.3	12.621	69.4

Weighted Average Magnesium Sulfate Loss of Coarse Aggregates

The weighted average magnesium sulfate loss of coarse aggregates were computed from the magnesium sulfate losses of 19.0-mm to 9.5-mm aggregate fraction passing 8.0-mm sieve, the magnesium sulfate losses of 9.5-mm to 4.75-mm aggregate fraction passing 4.0-mm sieve, and the original average percent retained on 12.5-mm, 9.5-mm, and 4.75-mm sieves (from Table 2-1). The computation was performed according to Eq.1.

The computed weighted average magnesium sulfate losses for coarse aggregates for the 6 pairs of proficiency samples were analyzed to determine the precision estimates for AASHTO T 104. Table 2-7 displays the results of the analyses. The plots of the weighted average magnesium sulfate percent loss of coarse aggregates for the 6 pairs of the proficiency samples are found in Appendix F.

Table 2-7- Summary Table for Magnesium Sulfate-Weighted Average Percentage Loss of Coarse Aggregate

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
141 & 142	113	0.44	0.44	0.095	21.7	21.5	0.190	43.5	0.205	46.7
145 & 146	118	1.18	1.16	0.272	22.9	23.5	0.751	63.4	0.773	66.8
149 & 150	117	1.65	1.55	0.311	18.9	20.2	0.914	55.4	0.876	56.7
153 & 154	144	14.76	14.91	1.674	9.4	11.2	9.486	64.3	9.351	62.7
157 & 158	143	0.70	0.72	0.157	22.3	21.7	0.439	62.3	0.441	61.0
161 & 163	142	12.55	12.48	1.565	12.5	12.5	8.404	67.0	8.510	68.2

A review of the data shown in Table 2-7 indicates that there is a trend between the average and standard deviation of the percent soundness loss; therefore, the form of the precision estimates should be based on the sample coefficient of variation. The average repeatability sample coefficient of variation for the four pairs of samples analyzed is 18.2 percent. The corresponding average reproducibility sample coefficient of variation is 59.8 percent.

2.2.2 Fine Aggregate Sulfate Soundness Percentage Loss

2.2.2.1 Sieve Analysis Results of Fine Aggregate

A summary of the results of sieve analysis of the 6 pairs of PSP fine aggregates are summarized in Table 2-8. The percent passing of 2.36-mm, 1.18-mm, 600-micron, and 300-micron sieves were used to compute percent retained on 1.18-mm, 600-micron, and 300-micron sieves for computing weighted loss of fine aggregates.

Table 2-8- Summary Table for Sieve Analysis of Fine Aggregate: Percent Material Passing

Sample Number	Average No. of Labs	2.36 mm	1.18 mm	600 μm	300 μm
143 & 144	1019	86.19	78.92	59.83	20.65
147 & 148	1018	86.83	76.42	58.30	27.03
151 & 152	1141	86.81	73.30	54.44	22.59
155 & 156	1155	86.48	76.14	55.57	16.74
159 & 160	1198	88.18	76.90	48.43	12.92
163 & 164	1268	84.49	74.26	46.60	13.20

2.2.2.2 Fine Aggregate Percentage Loss by Sodium Sulfate

Fraction Passing 1.18-mm Sieve

The reported sodium sulfate-percentage losses of material finer than the 1.18-mm sieve were analyzed for 6 pairs of proficiency samples. Table 2-9 displays the results of the analyses. The plots of the sodium sulfate percent loss data of material finer than 1.18-mm sieve of the 6 pairs of proficiency samples are found in Appendix G.

Table 2-9- Summary Table for Sodium Sulfate-Percentage Loss of Fraction Finer than 1.18-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples CV%	Even Samples CV%	Odd Samples 1s	Odd Samples CV%	Even Samples 1s	Even Samples CV%
143 & 144	234	1.64	1.65	0.259	15.7	15.7	0.916	55.8	0.902	54.6
147 & 148	230	1.75	1.77	0.236	13.5	13.3	0.899	51.4	0.927	52.3
151 & 152	259	1.68	1.63	0.242	14.4	14.9	0.822	48.9	0.768	47.1
155 & 156	272	1.90	1.91	0.307	16.2	16.1	0.966	50.9	1.013	53.1
159 & 160	283	3.10	3.17	0.356	11.48	11.224	1.768	57.0	1.796	56.6
163 & 164	290	1.71	1.71	0.253	14.75	14.774	0.920	53.7	0.918	53.7

Fraction Passing 600-micron Sieve

The sodium sulfate-percentage losses of material finer than the 600-micron sieve were analyzed for 6 pairs of proficiency samples. Table 2-10 displays the results of the analyses. The plots of the sodium sulfate percent loss data of material finer than 600-μm sieve for the 6 pairs of proficiency samples are found in Appendix H.

Table 2-10- Summary Table for Sodium Sulfate-Percentage Loss of Fraction Finer than 600-μm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	221	1.78	1.79	0.279	15.7	15.6	1.265	71.3	1.216	68.0
147 & 148	227	1.69	1.78	0.318	18.8	17.9	0.961	56.9	0.982	55.3
151 &152	245	1.72	1.71	0.222	12.9	13.0	0.928	54.0	0.911	53.4
155 & 156	263	1.88	1.94	0.358	19.1	18.5	1.008	53.7	1.062	54.8
159 & 160	272	2.21	2.30	0.346	15.7	15.1	1.310	59.4	1.421	61.9
163 & 164	279	1.61	1.61	0.268	16.6	16.6	0.906	56.2	0.900	55.9

Fraction Passing 300-micron Sieve

The sodium sulfate-percentage loss of material finer than 300-micron sieve was analyzed for 6 pairs of proficiency samples. Table 2-11 displays the results of the analyses. The plots of the sodium sulfate percent loss data of material finer than 300-μm sieve for the 6 pairs of proficiency samples are found in Appendix I.

Table 2-11- Summary Table for Sodium Sulfate-Percentage Loss of Fraction Finer than 300-μm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	222	1.56	1.62	0.311	20.0	19.2	0.986	63.3	1.029	63.5
147 & 148	228	1.63	1.64	0.294	18.0	17.9	1.147	70.3	1.100	66.9
151 &152	247	1.49	1.57	0.274	18.4	17.4	0.905	60.7	0.962	61.3
155 & 156	254	1.56	1.59	0.257	16.5	16.2	0.912	58.5	0.957	60.3
159 & 160	270	1.73	1.77	0.248	14.3	14.0	1.148	66.2	1.174	66.5
163 & 164	277	1.73	1.78	0.325	18.8	18.3	1.231	71.2	1.231	69.3

Weighted Average Sodium Sulfate Loss of Fine Aggregates

The weighted average sodium sulfate loss of fine aggregates were computed using the sodium sulfate losses of aggregates finer than 1.18-mm, 600-μm, and 300-μm sieves and the original average percent retained on the corresponding sieves (from Table 2-8). The computation was performed according to Eq. 2:

$$\text{Weighted Loss} = \frac{L_{1.18} * R_{1.18} + L_{600} * R_{600} + L_{300} * R_{300}}{R_{1.18} + R_{600} + R_{300}} \qquad \text{(Eq. 2)}$$

$L_{1.18}$ = % loss on 1.18-mm sieve

L_{600} = % loss on 600-μm sieve

L_{300} = % loss on 300-μm sieve

$R_{1.18}$ = % retained on 1.18-mm sieve

R_{600}= % retained on 600-μm sieve

R_{300}= % retained on 300-μm sieve

The computed weighted average sodium sulfate losses for fine aggregates for the 6 pairs of proficiency samples were analyzed to determine the precision estimates for T104. Table 2-12 displays the results of the analyses. The plots of weighted average sodium sulfate percent loss of fine aggregates for the 6 pairs of proficiency samples are found in Appendix J.

Table 2-12- Summary Table for Sodium Sulfate-Weighted Average Percentage Loss of Fine Aggregate

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	225	1.72	1.75	0.273	15.9	15.6	1.005	58.6	1.009	57.8
147 & 148	223	1.70	1.72	0.197	11.6	11.4	0.885	51.9	0.864	50.2
151 &152	238	1.58	1.61	0.167	10.6	10.4	0.729	46.2	0.745	46.4
155 & 156	263	1.78	1.80	0.234	13.1	13.0	0.878	49.4	0.919	50.9
159 & 160	272	2.15	2.23	0.230	10.7	10.4	1.1	53.2	1.213	54.5
163 & 164	282	1.84	1.83	0.243	13.2	13.2	0.9	51.4	0.938	51.1

A review of the data shown in Table 2-12 indicates that there is a trend between the average and standard deviation of the percent soundness loss; therefore, the form of the precision estimates should be based on the sample coefficient of variation. The average repeatability sample coefficient of variation for the 6 pairs of samples analyzed is 12.4 percent. The corresponding average reproducibility sample coefficient of variation is 51.8 percent.

2.2.2.3 Fine Aggregate Percentage Loss by Magnesium Sulfate

Fraction Passing 1.18-mm Sieve

The magnesium sulfate-percentage loss of material finer than the 1.18-mm sieve was analyzed for 6 pairs of proficiency samples. Table 2-13 displays the results of the analyses. The plots of the magnesium sulfate percent loss data of material finer than 1.18-mm sieve for the 6 pairs of proficiency samples are found in Appendix K.

Table 2-13- Summary Table for Magnesium Sulfate-Percentage Loss of Fraction Passing 1.18-mm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	104	3.70	3.81	0.634	17.1	16.7	1.911	51.6	2.054	54.0
147 & 148	101	4.05	4.07	0.443	10.9	10.9	1.982	48.9	1.983	48.8
151 &152	126	4.09	4.01	0.488	12.0	12.2	1.688	41.3	1.595	39.8
155 & 156	127	4.15	4.11	0.495	11.9	12.0	1.930	46.6	1.894	46.1
159 & 160	130	6.92	7.03	0.716	10.4	10.2	3.550	51.3	3.515	50.0
163 & 164	119	3.99	4.08	0.465	11.6	11.4	2.117	53.0	2.092	51.3

Fraction Passing 600-micron Sieve

The magnesium sulfate-percentage loss of material finer than the 600-µm sieve was analyzed for 6 pairs of proficiency samples. Table 2-14 displays the results of the analyses. The plots of the magnesium sulfate percent loss of material finer than 600-µm sieve for the 6 pairs of proficiency samples are found in Appendix L.

Table 2-14- Summary Table for Magnesium Sulfate-Percentage Loss of Fraction Passing 600-µm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	97	3.58	3.61	0.509	14.2	14.1	1.980	55.3	2.069	57.2
147 & 148	100	3.57	3.77	0.460	12.9	12.2	1.731	48.5	1.798	47.7
151 &152	126	3.75	3.73	0.558	14.9	15.0	1.721	45.9	1.657	44.4
155 & 156	122	3.99	4.00	0.534	13.4	13.4	2.011	50.4	2.097	52.5
159 & 160	115	5.13	5.21	0.433	8.4	8.3	2.637	51.4	2.676	51.4
163 & 164	113	3.50	3.55	0.510	14.6	14.4	1.690	48.2	1.686	47.4

Fraction Passing 300-micron Sieve

The reported magnesium sulfate-percentage loss of material finer than the 300-µm sieve was analyzed for 6 pairs of proficiency samples. Table 2-15 displays the results of the analyses. The plots of the magnesium sulfate percent loss of fine aggregate passing 300-µm sieve for the 6 pairs of proficiency samples are found in Appendix M.

Table 2-15- Summary Table for Magnesium Sulfate-Percentage Loss of Fraction Passing 300-μm Sieve

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	91	3.13	3.05	0.478	15.3	15.7	1.603	51.2	1.539	50.4
147 & 148	104	3.29	3.52	0.493	15.0	14.0	1.684	51.2	1.706	48.4
151 &152	119	3.25	3.21	0.388	11.9	12.1	1.657	51.0	1.576	49.1
155 & 156	123	3.51	3.41	0.495	14.1	14.5	1.617	46.1	1.578	46.3
159 & 160	121	4.69	4.72	0.450	9.6	9.5	2.432	51.8	2.516	53.3
163 & 164	112	3.31	3.18	0.458	13.9	14.4	1.884	57.0	1.797	56.5

Weighted Average Magnesium Sulfate Loss of Fine Aggregates

The weighted average magnesium sulfate loss of fine aggregates were computed using the magnesium sulfate losses of aggregates finer than 1.18-mm, 600-μm, and 300-μm sieves and the average percent retained on the corresponding sieves (from Table 2-8). The computations were performed according to Eq. 2.

The computed weighted average magnesium sulfate losses for fine aggregates for the four pairs of proficiency sample were analyzed to determine the precision estimates for AASHTO T104. Table 2-16 displays the results of the analyses. The Plots of the weighted average magnesium sulfate loss of fine aggregates are found in Appendix N.

Table 2-16- Summary Table for Magnesium Sulfate-Weighted Average Percentage Loss of Fine Aggregate

Sample Number	No. of Labs	Average Results		Repeatability			Reproducibility		Reproducibility	
		Odd Samples	Even Samples	1s	Odd Samples	Even Samples	Odd Samples	Odd Samples	Even Samples	Even Samples
					CV%	CV%	1s	CV%	1s	CV%
143 & 144	90	3.27	3.27	0.305	9.4	9.3	1.531	46.9	1.545	47.2
147 & 148	98	3.45	3.65	0.343	9.9	9.4	1.530	44.3	1.595	43.7
151 & 152	118	3.53	3.50	0.283	8.0	8.1	1.413	40.0	1.365	39.0
155 & 156	117	3.80	3.76	0.303	8.0	8.1	1.680	44.2	1.706	45.3
159 & 160	118	5.18	5.21	0.331	6.4	6.4	2.47	47.7	2.520	48.3
163 & 164	113	3.66	3.61	0.594	16.2	16.5	1.60	43.7	1.617	44.8

A review of the data shown in Table 2-16 indicates that the form of the precision estimates should be based on the sample coefficient of variation. The average repeatability sample coefficient of variation for the four pairs of samples analyzed is 9.6 percent. The corresponding average reproducibility sample coefficient of variation is 44.6 percent.

2.2.3 Comparison of the Computed and Existing Precision Estimates

The precision estimates computed in this study and the precision estimates existing in AASHTO T 104-99(2003) are provided in Table 2-17. The comparison of the new and existing precisions for soundness testing of coarse aggregate indicates that the analysis in this study resulted in the improvement of only single operator precision of sodium sulfate and all other precisions got worse. The repeatability and reproducibility coefficient of variations of both new and existing precisions are so large that their applicability within and between-laboratory comparisons are uncertain. The improvement of the precisions of the test requires a comprehensive ruggedness testing that involves examination of the key variables of the test method.

Table 2-17- Comparison of the New and Existing T 104 Precision Estimates

Material and Type Index	Coefficient of Variation (1s%), Percent	Difference Between Two Tests (d2s) Percent of Average	Coefficient of Variation (1s%), Percent	Difference Between Two Tests (d2s) Percent of Average
	New Precisions:		Existing Precisions (AASHTO T104-99(2003):	
Single-Operator Precision:				
Coarse aggregate				
Sodium Sulfate	19	53	24	68
Magnesium Sulfate	18	51	11	31
Fine aggregate				
Sodium Sulfate	12	35	-	-
Magnesium Sulfate	10	27	-	-
Multilaboratory Precision:				
Coarse aggregate				
Sodium Sulfate	68	190	41	116
Magnesium Sulfate	60	168	25	71
Fine Aggregate:				
Sodium Sulfate	52	145	-	-
Magnesium Sulfate	45	125	-	-

CHAPTER 3. CONCLUSIONS AND RECOMMENDATIONS

3.1 COMMENTARY

This study was conducted to update the precision estimates for AASHTO Standard Test Method T 104, "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate." Six of the most recent AMRL proficiency data sets that reflect the 1999 revisions to AASHTO 104 were analyzed to derive the precision estimates. In most cases the data sets were collected from well over 100 laboratories. The data sets were selected to include a wide range of sodium and magnesium sulfate soundness values.

3.2 CONCLUSION

The precision and bias statement currently published in T104-99 (2003) was found in need of revision. The existing statement only covers the precision estimates for sulfate soundness loss of coarse aggregate and does not include precisions for testing fine aggregate. Furthermore, as indicated from the existing T 104 precision statement, the variability of the test is quite high; the footnote of the test method states possible improvements of the precisions if the test is conducted according to the test method revised in 1991. To include the precisions for soundness of fine aggregate and to reflect the 1991 revisions of the test method in the precision statement, the most recent sets of AMRL proficiency sulfate soundness loss data were analyzed. The precision estimates developed in this study (Section 2.2.6) indicate that the variability of the sulfate soundness loss is in most cases even larger than the variability reported in the existing test method. The reason for this difference is not clear since the factors involved in the development of the existing precisions are unknown. A possible reason for the higher variability may be the smaller range of sulfate soundness loss of AMRL proficiency samples than the data sets used in the development of the existing precisions.

3.3 RECOMMENDATIONS

Regardless of using the data collected prior or after the 1991 revisions of AASHTO T 104, the computed coefficient of variations of the test method are undoubtedly high. This deems the use of the repeatability and reproducibility estimates for the within and between laboratory comparisons ineffective. To improve the variability of the AASHTO T 104 test results, it is recommended that the factors causing the high variability of the test to be identified. A comprehensive ruggedness testing plan would determine the limits of the test factors that have the most effect on the sulfate soundness loss of fine and coarse aggregates.

3.4 PRECISION STATEMENT FOR AASHTO T 104 SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE OR MAGNESIUM SULFATE

X. Precision and Bias

X.1 Precision - Criteria for judging the acceptability of percentages loss of aggregates by sulfate soundness test that are obtained using T 104 are given in Table X:

Note- The figures in Column 2 are the coefficients of variation that have been found to be appropriate for the materials and conditions of test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests as a percent of their mean.

Table X – Precision Estimates For AASHTO T 104

	Coefficient of Variation (1s%), Percent of Mean[a]	Difference Between Two Tests (d2s) Percent of Mean[a]
Single-Operator precision:		
Coarse aggregate		
Sodium Sulfate	19	53
Magnesium Sulfate	18	51
Fine aggregate		
Sodium Sulfate	12	35
Magnesium Sulfate	10	27
Multilaboratory Precision:		
Coarse aggregate		
Sodium Sulfate	68	190
Magnesium Sulfate	60	168
Fine Aggregate:		
Sodium Sulfate	52	145
Magnesium Sulfate	45	125

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

Note – The precision estimates given in Table X are based on the analysis of weighted average of sulfate soundness loss test results from 60 pairs of AMRL proficiency samples. The data analyzed consisted of results from 90 to 282 laboratories for each of the pairs of samples. The analysis of coarse aggregate sulfate soundness included 19.0-mm to 4.75-mm aggregate with the weighted average sodium sulfate loss of 0.3% to 3.5 % and average magnesium sulfate loss of 0.4% to 14.9%. The analysis of fine aggregate sulfate soundness included 1.18-mm to 300-micron fine aggregate with the average sodium sulfate loss of 1.7% to 2.2% and average magnesium sulfate loss of 3.3% to 5.21%.

X.2 Bias – No information can be presented on the bias of the procedure because no comparison with the material having an accepted reference value was conducted.

REFERENCES:

[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.

[2] Spellerberg, P.A. and Savage, D.A., "An Investigation of the Cause of Variation in HMA Bulk Specific Gravity Test Results Using Non-Absorptive Aggregates," NCHRP Web Document 66, 2004.

[3] Holsinger, R.E., Fisher, A., and Spellerberg, P.A., "Precision Estimates for AASHTO Test Method T308 and the Test Methods for Performance-Graded Asphalt Binder in AASHTO Specification M320," NCHRP Web Document 71, 2005.

[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

[5] Azari, H., Lutz, R., and Spellerberg, P., "Precision Estimates for AASHTO Test Method T269 Determined Using AMRL Proficiency Sample data," Submitted for Approval by the NCHRP 9-26 Panel

[6] AASHTO, Designation T104, "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate," Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 27th Edition, AASHTO, Washington, DC, 2007, CD-ROM.

[7] Pielert, J.H. and Spellerberg, P.A., "AASHTO Materials Reference Laboratory – Thirty Years of Service to the Transportation Community," TR News, Number 183, Transportation Research Board, Washington, DC, March-April 1996, pages 22-28.

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

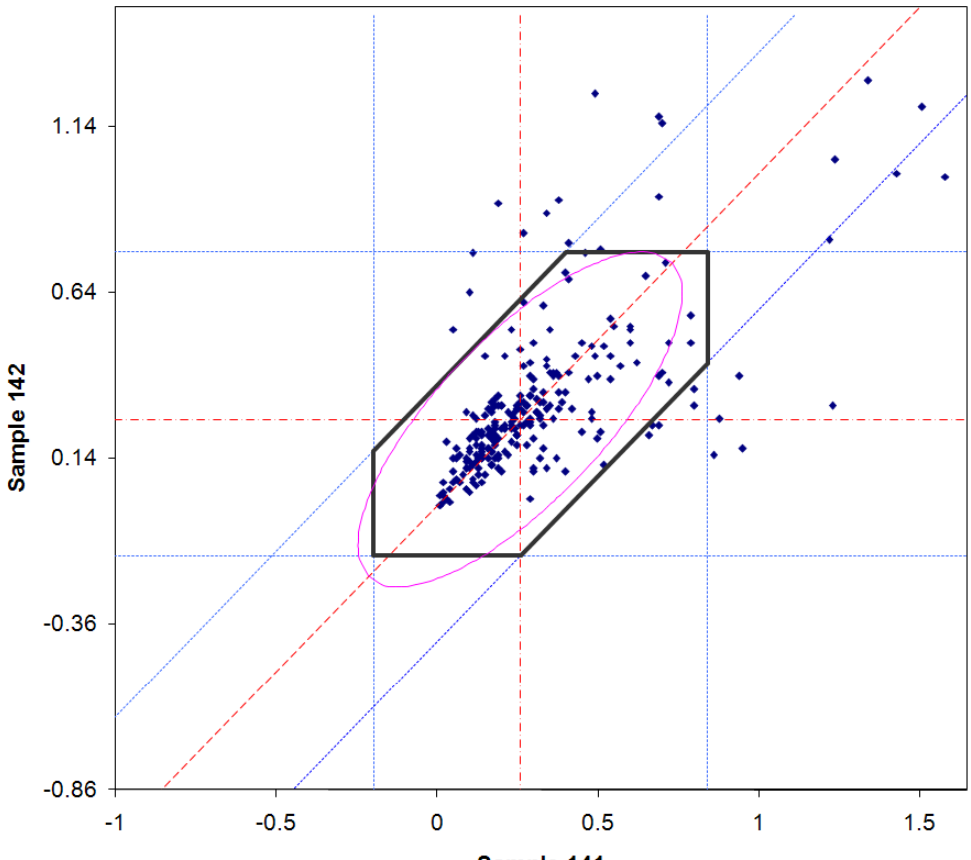
APPENDIX A: SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, COARSE AGGREGATES: 19.0-MM TO 9.5-MM PASSING 8.0-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

251	Total Laboratories
12	Laboratories Determined to be Invalid
24	Laboratories Determined to be Outliers
215	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.258	0.258

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.084	0.237	32.50	32.51

Reproducability (Sample 141)		
1s	d2s	CV%
0.164	0.465	63.71

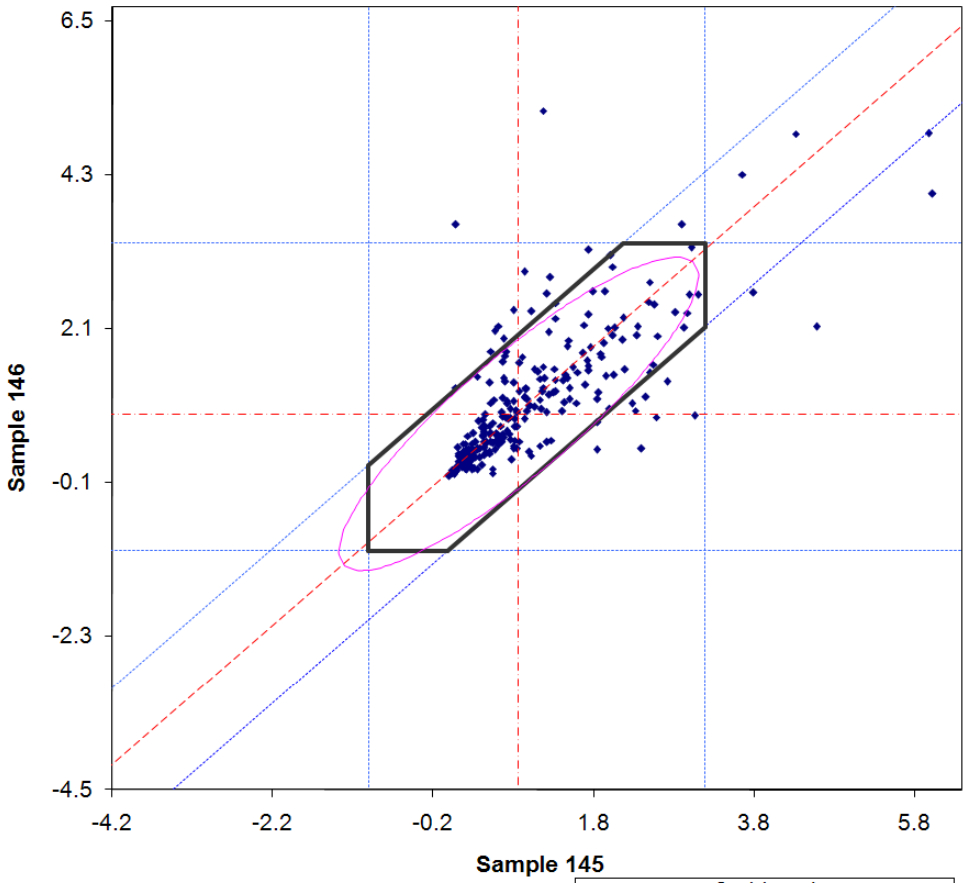
Reproducability (Sample 142)		
1s	d2s	CV%
0.150	0.424	58.16

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

274	Total Laboratories
12	Laboratories Determined to be Invalid
23	Laboratories Determined to be Outliers
239	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
0.866	0.886

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.260	0.736	30.02	29.36

Reproducability (Sample 145)		
1s	d2s	CV%
0.722	2.041	83.29

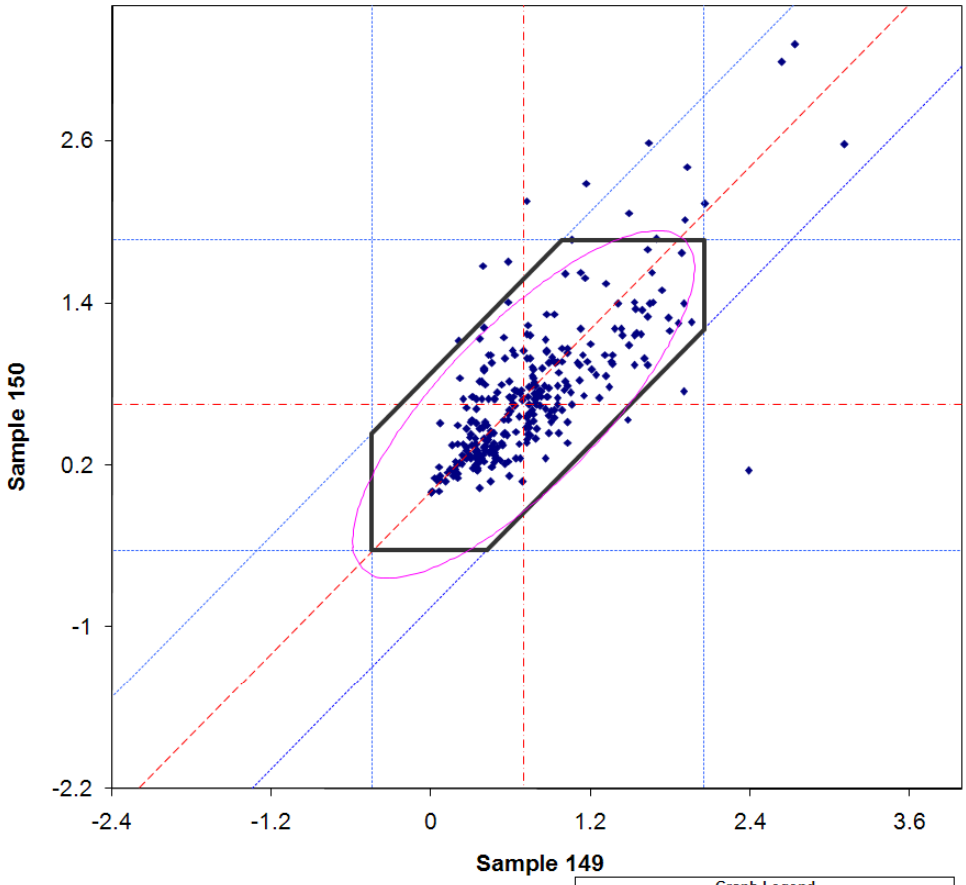
Reproducability (Sample 146)		
1s	d2s	CV%
0.726	2.052	81.89

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

303	Total Laboratories
5	Laboratories Determined to be Invalid
14	Laboratories Determined to be Outliers
284	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
0.696	0.652

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.198	0.560	28.46	30.41

Reproducability (Sample 149)		
1s	d2s	CV%
0.424	1.200	60.95

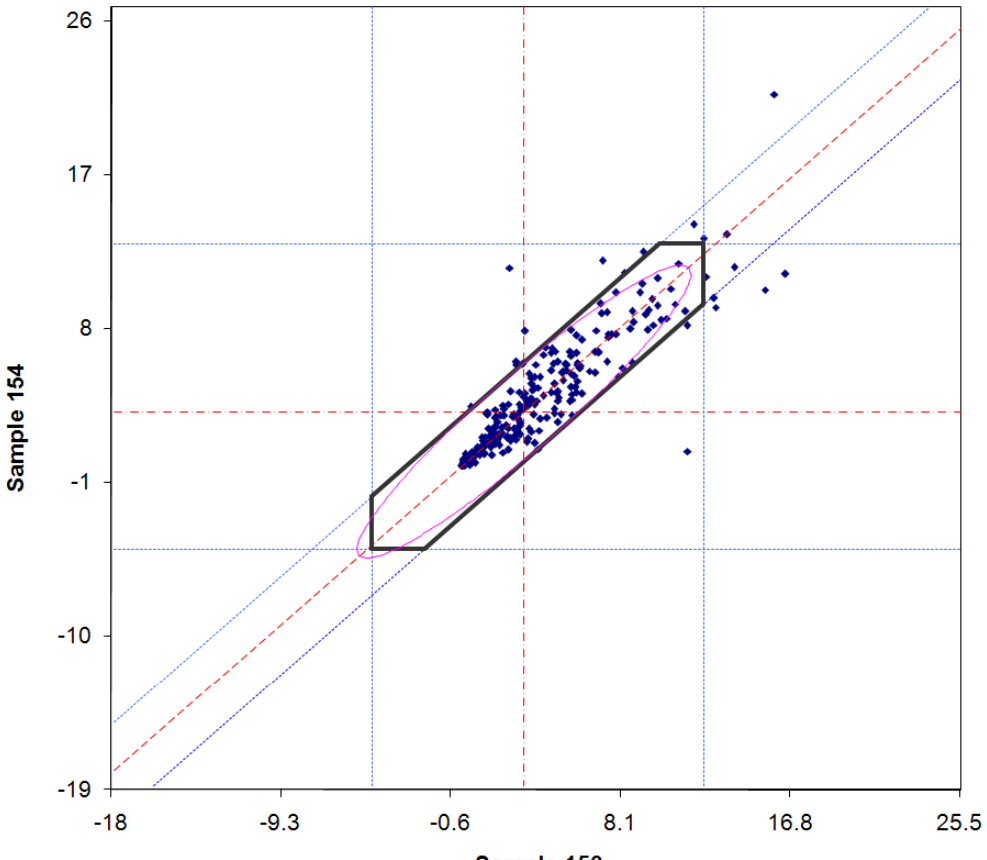
Reproducability (Sample 150)		
1s	d2s	CV%
0.385	1.090	59.16

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

297	Total Laboratories
7	Laboratories Determined to be Invalid
18	Laboratories Determined to be Outliers
272	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
3.164	3.143

Repeatability			
1s	d2s	CV% (153)	CV% (154)
0.677	1.916	21.41	21.56

Reproducability (Sample 153)		
1s	d2s	CV%
2.819	7.972	89.09

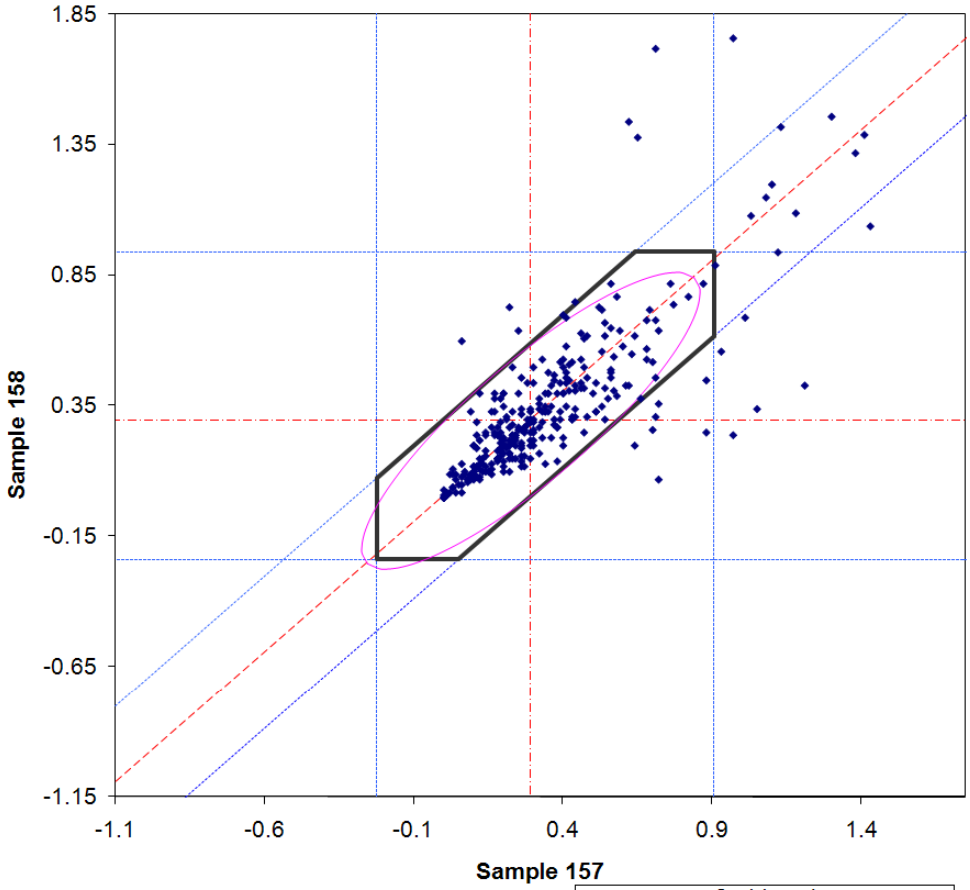
Reproducability (Sample 154)		
1s	d2s	CV%
2.816	7.965	89.60

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

320	Total Laboratories
24	Laboratories Determined to be Invalid
23	Laboratories Determined to be Outliers
273	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.292	0.293

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.071	0.200	24.20	24.11

Reproducability (Sample 157)		
1s	d2s	CV%
0.182	0.515	62.36

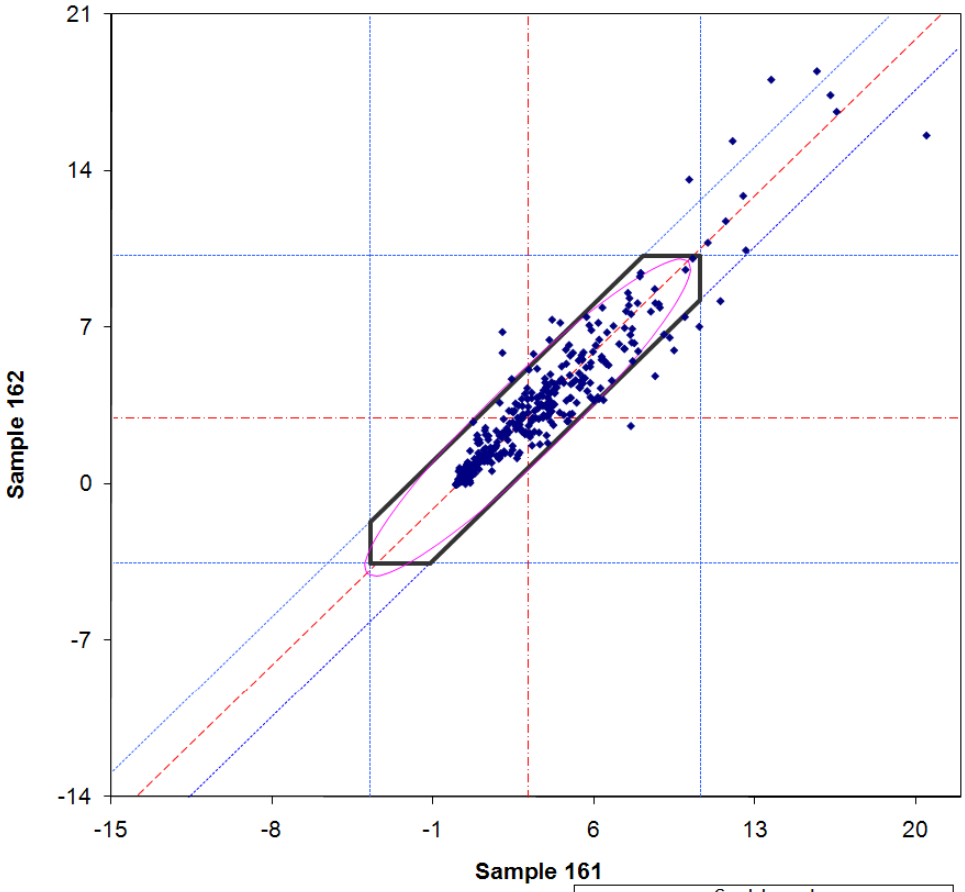
Reproducability (Sample 158)		
1s	d2s	CV%
0.183	0.517	62.35

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Soundness Test Using Sodium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

350	Total Laboratories
10	Laboratories Determined to be Invalid
19	Laboratories Determined to be Outliers
321	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
3.120	2.977

Repeatability			
1s	d2s	CV% (161)	CV% (162)
0.559	1.582	17.93	18.79

Reproducability (Sample 161)		
1s	d2s	CV%
2.385	6.745	76.43

Reproducability (Sample 162)		
1s	d2s	CV%
2.267	6.413	76.17

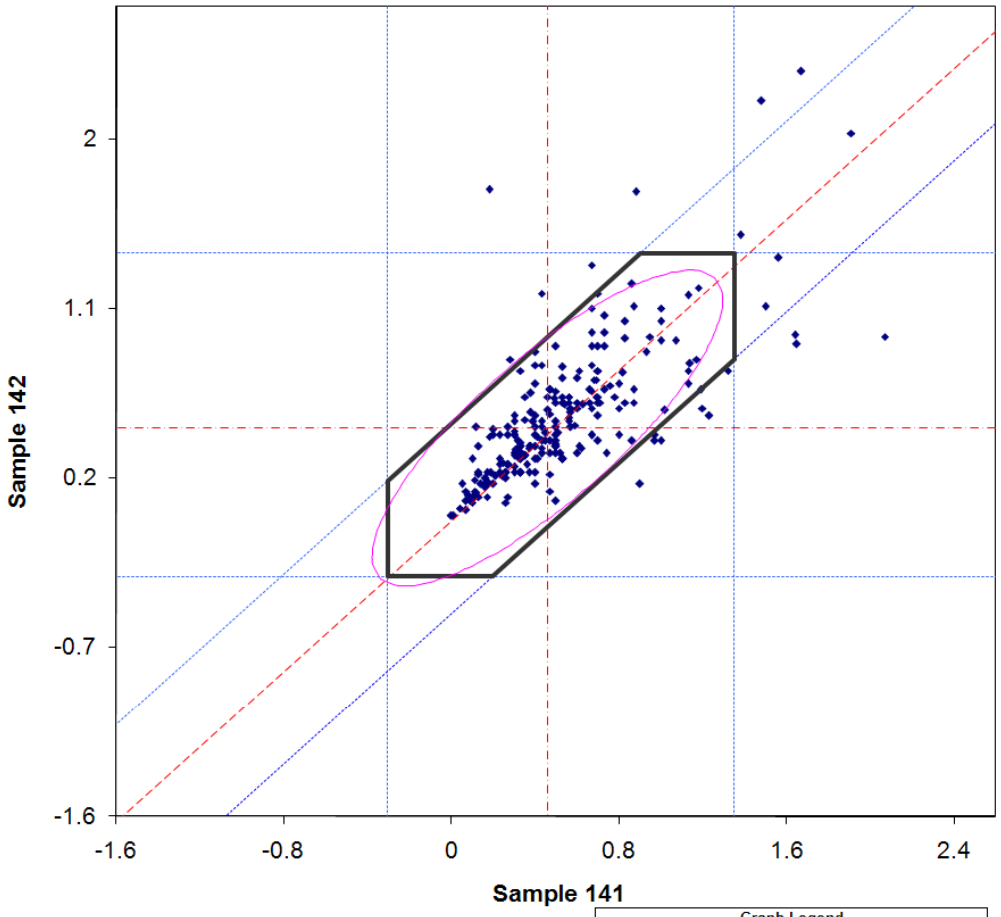
APPENDIX B: SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, COARSE AGGREGATES 9.5-MM TO 4.75-MM PASSING 4.0-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

266	Total Laboratories
21	Laboratories Determined to be Invalid
20	Laboratories Determined to be Outliers
225	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.459	0.464

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.120	0.339	26.09	25.78

Reproducability (Sample 141)		
1s	d2s	CV%
0.261	0.737	56.84

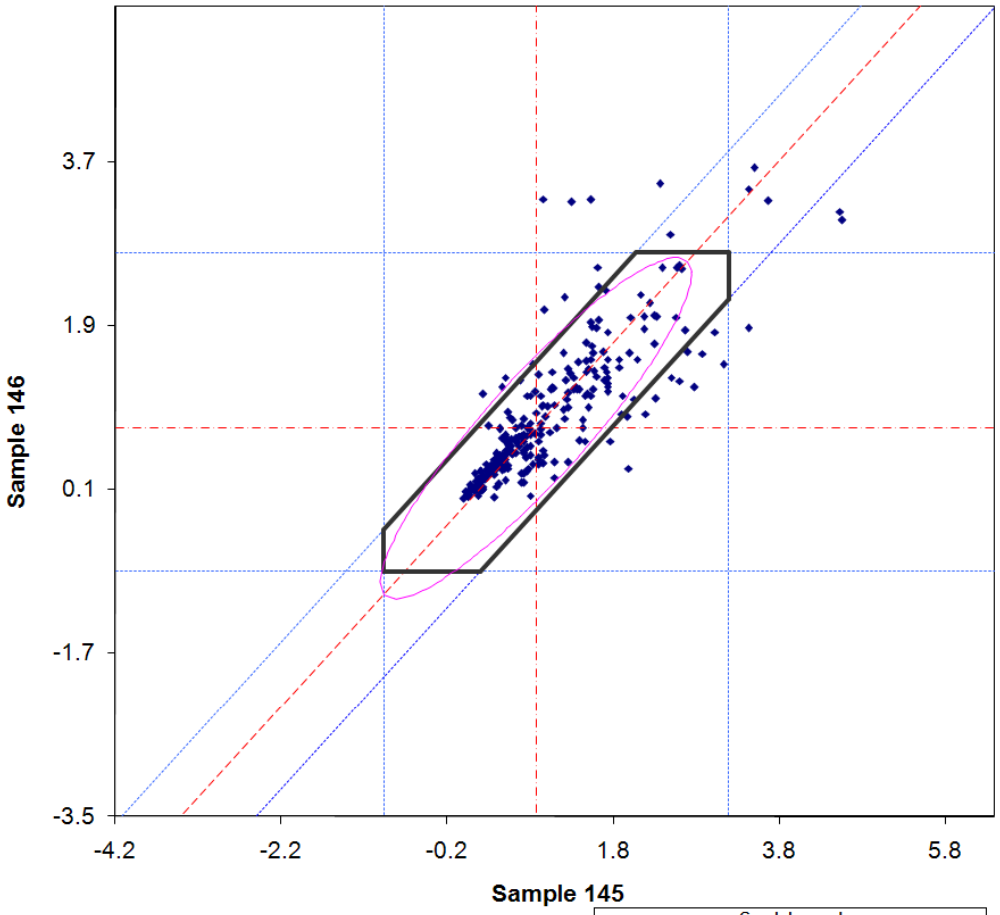
Reproducability (Sample 142)		
1s	d2s	CV%
0.271	0.767	58.42

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

274	Total Laboratories
7	Laboratories Determined to be Invalid
28	Laboratories Determined to be Outliers
239	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
0.871	0.772

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.193	0.547	22.21	25.06

Reproducability (Sample 145)		
1s	d2s	CV%
0.630	1.782	72.35

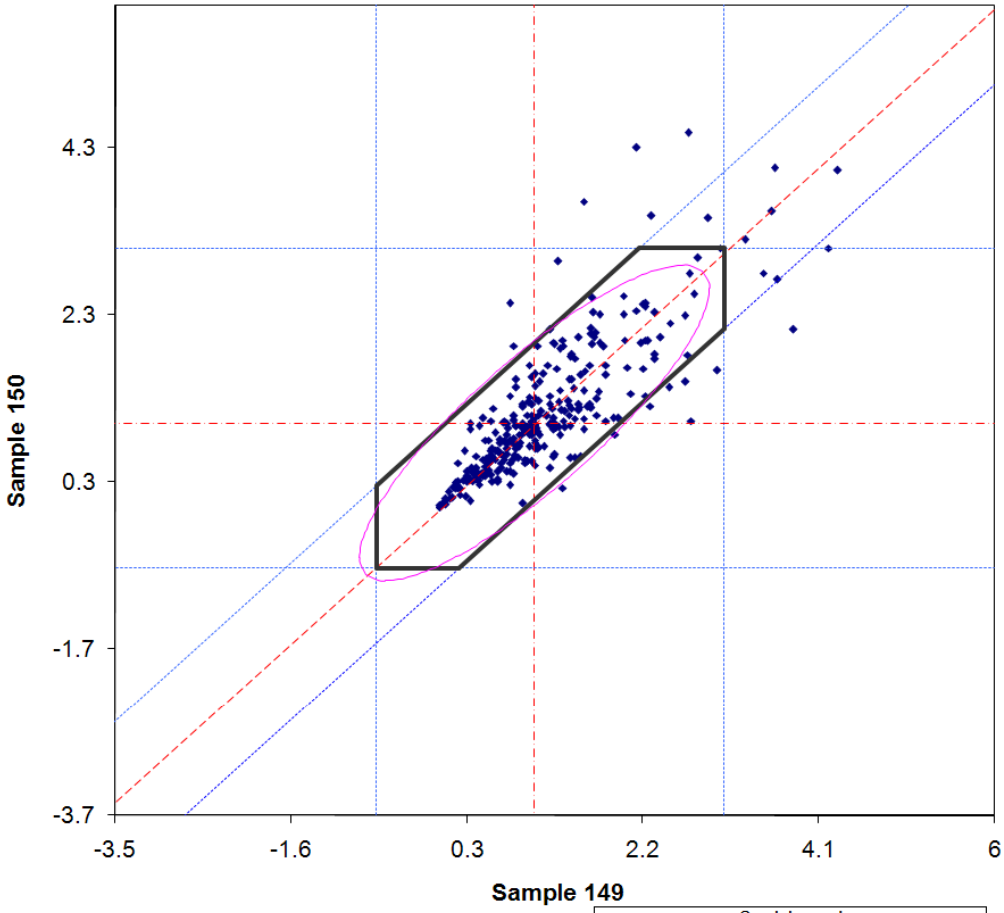
Reproducability (Sample 146)		
1s	d2s	CV%
0.588	1.663	76.20

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

303	Total Laboratories
5	Laboratories Determined to be Invalid
21	Laboratories Determined to be Outliers
277	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
1.026	1.005

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.241	0.683	23.52	24.00

Reproducability (Sample 149)		
1s	d2s	CV%
0.595	1.684	58.05

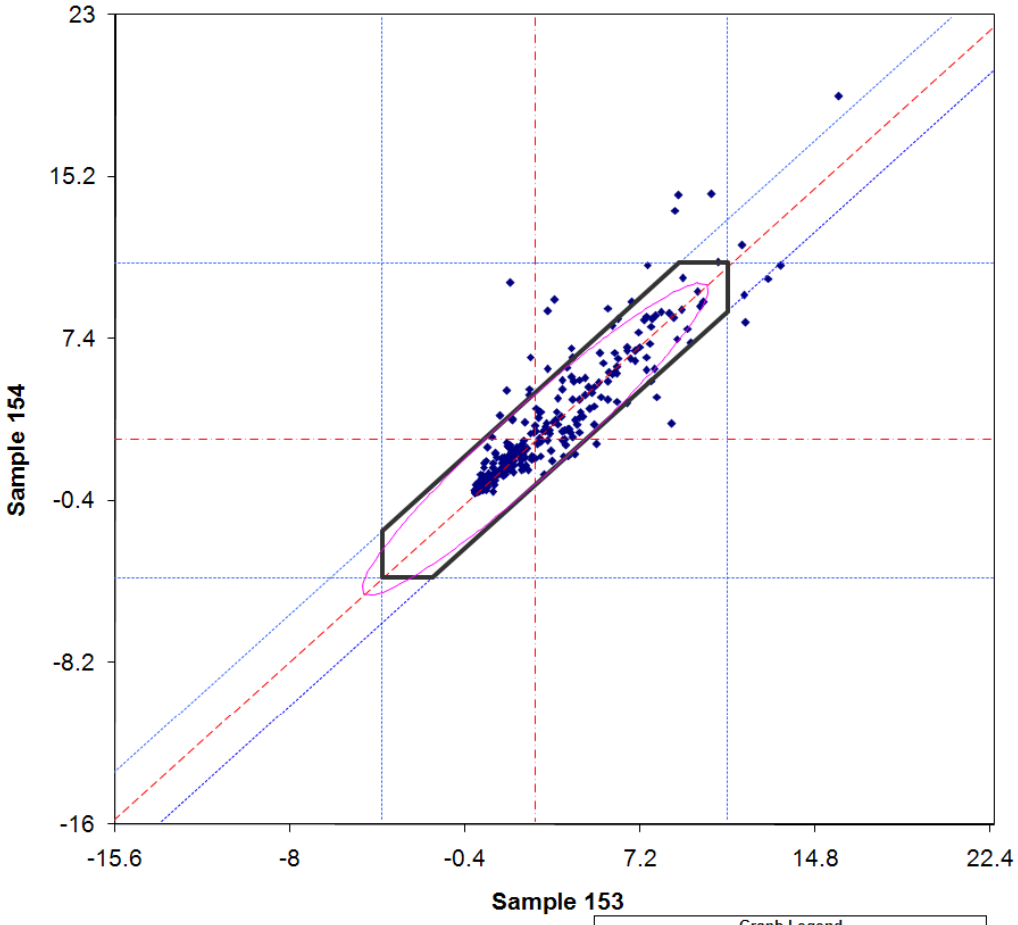
Reproducability (Sample 150)		
1s	d2s	CV%
0.616	1.744	61.31

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

298	Total Laboratories
11	Laboratories Determined to be Invalid
24	Laboratories Determined to be Outliers
263	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
2.637	2.576

Repeatability			
1s	d2s	CV% (153)	CV% (154)
0.517	1.463	19.62	20.08

Reproducability (Sample 153)		
1s	d2s	CV%
2.497	7.063	94.71

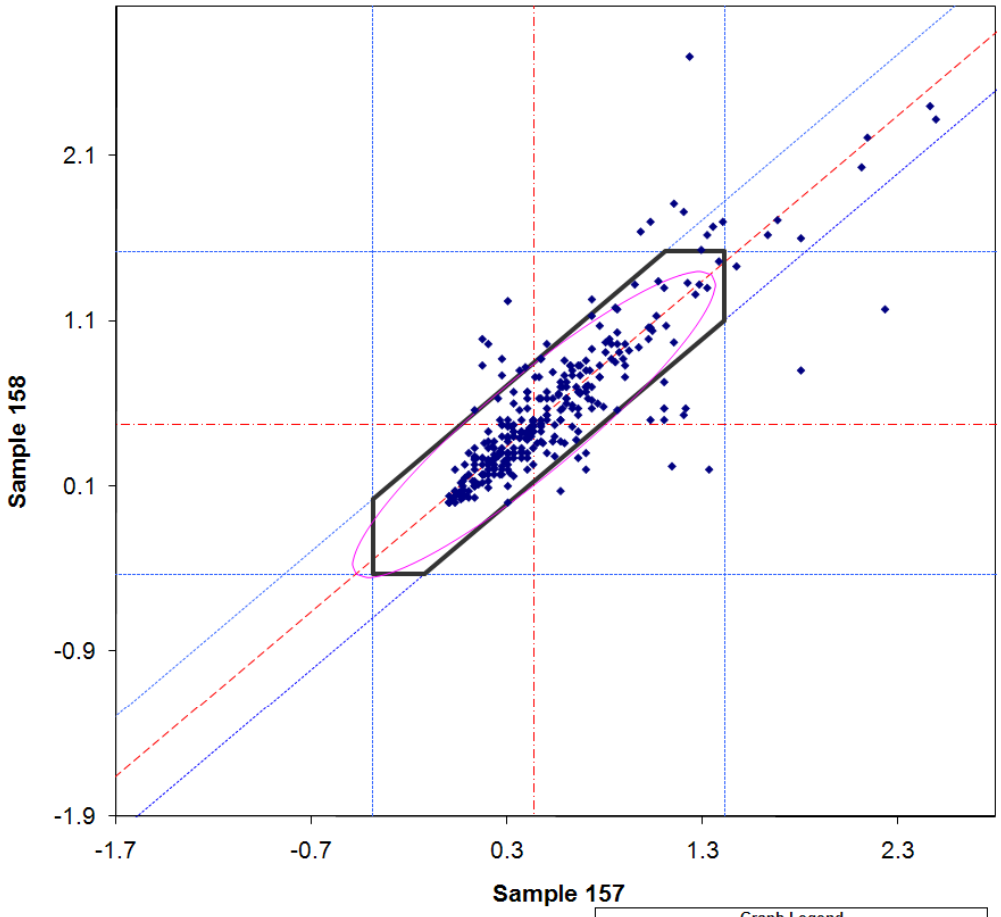
Reproducability (Sample 154)		
1s	d2s	CV%
2.465	6.973	95.71

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

320	Total Laboratories
12	Laboratories Determined to be Invalid
32	Laboratories Determined to be Outliers
276	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.437	0.474

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.089	0.250	20.23	18.66

Reproducability (Sample 157)		
1s	d2s	CV%
0.288	0.815	65.84

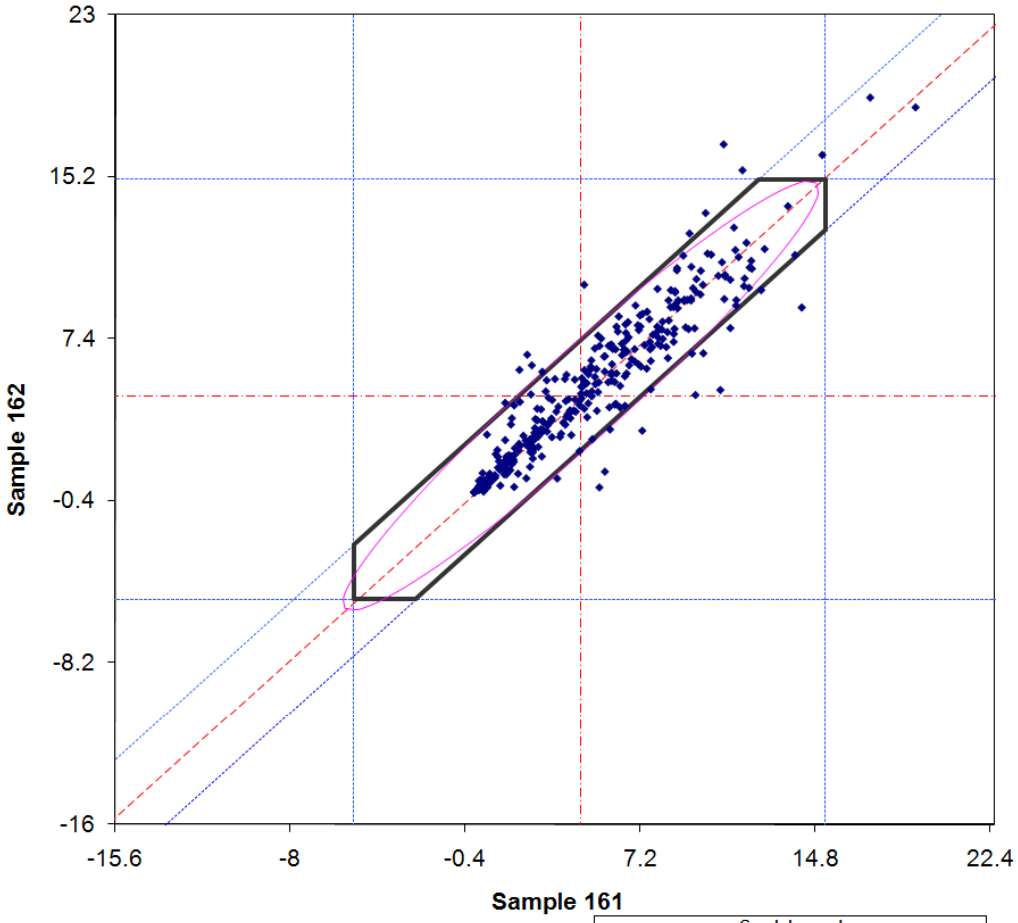
Reproducability (Sample 158)		
1s	d2s	CV%
0.317	0.895	66.74

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Soundness Test Using Sodium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

350	Total Laboratories
6	Laboratories Determined to be Invalid
21	Laboratories Determined to be Outliers
323	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
4.606	4.657

Repeatability			
1s	d2s	CV% (161)	CV% (162)
0.652	1.843	14.15	13.99

Reproducability (Sample 161)		
1s	d2s	CV%
3.415	9.660	74.15

Reproducability (Sample 162)		
1s	d2s	CV%
3.406	9.634	73.14

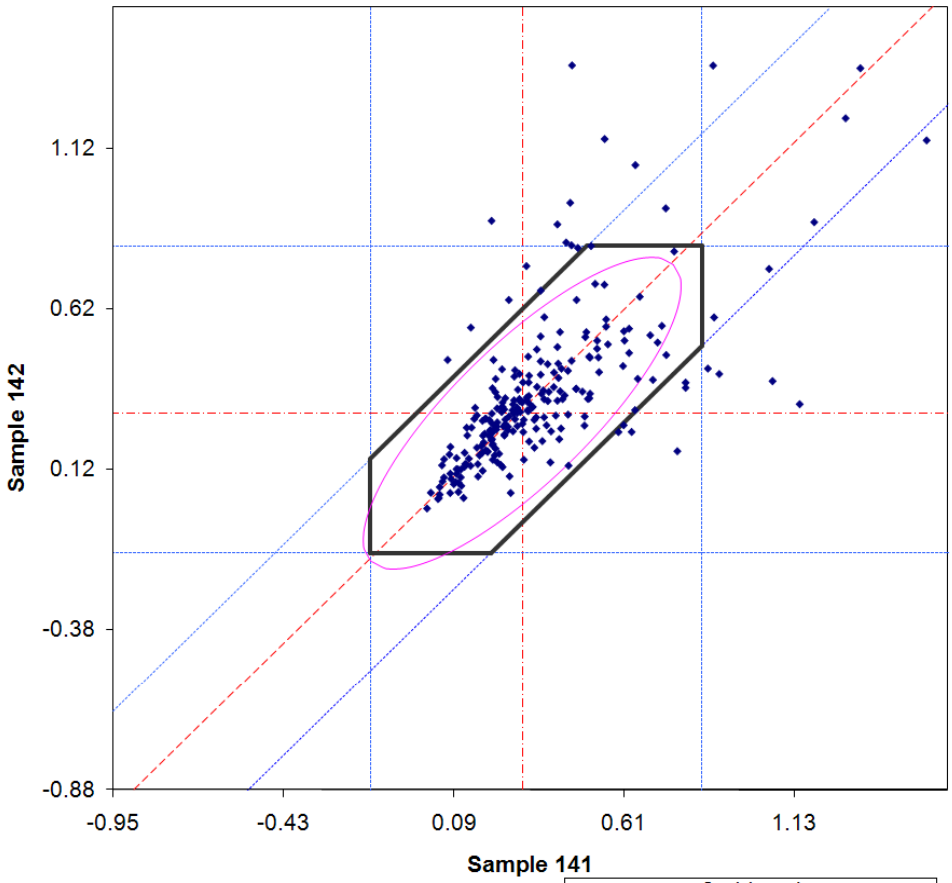
APPENDIX C: WEIGHTED AVERAGE SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, COARSE AGGREGATES

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

252	Total Laboratories
13	Laboratories Determined to be Invalid
26	Laboratories Determined to be Outliers
213	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.300	0.296

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.070	0.199	23.4	23.8

Reproducability (Sample 141)		
1s	d2s	CV%
0.161	0.454	53.5

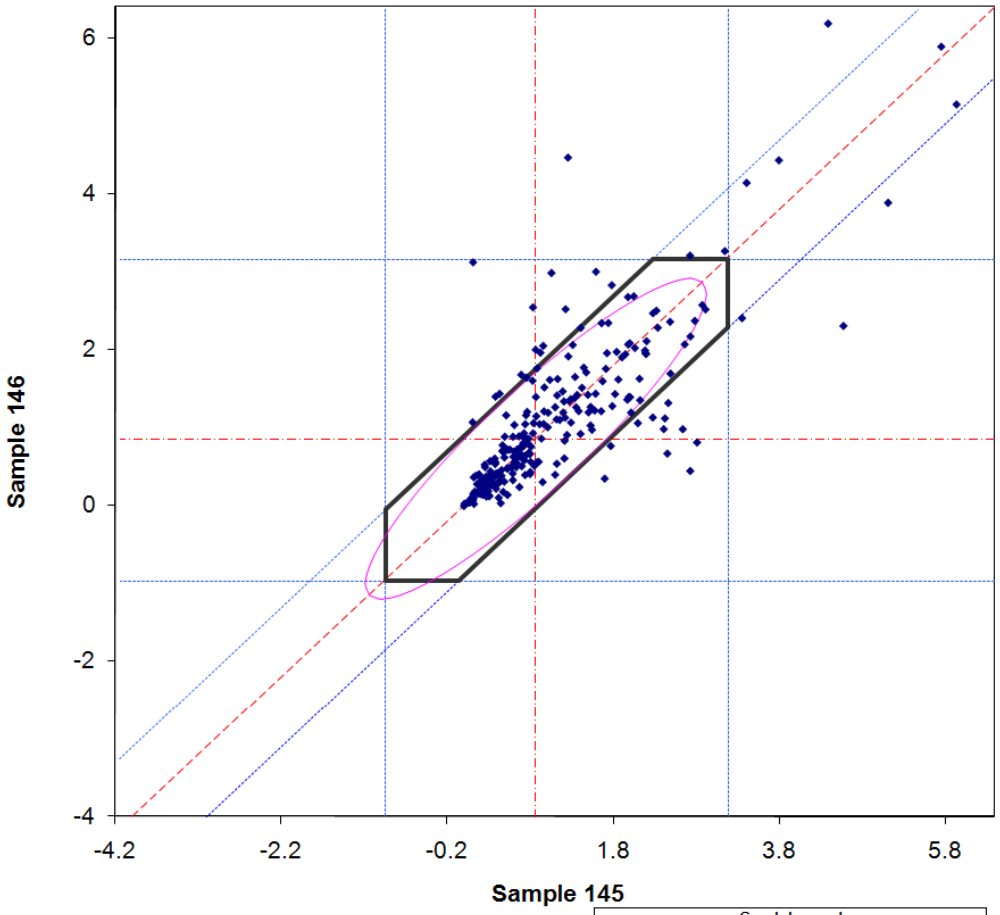
Reproducability (Sample 142)		
1s	d2s	CV%
0.147	0.416	49.8

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

273	Total Laboratories
13	Laboratories Determined to be Invalid
27	Laboratories Determined to be Outliers
233	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
0.865	0.857

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.206	0.582	23.8	24.0

Reproducability (Sample 145)		
1s	d2s	CV%
0.673	1.905	77.8

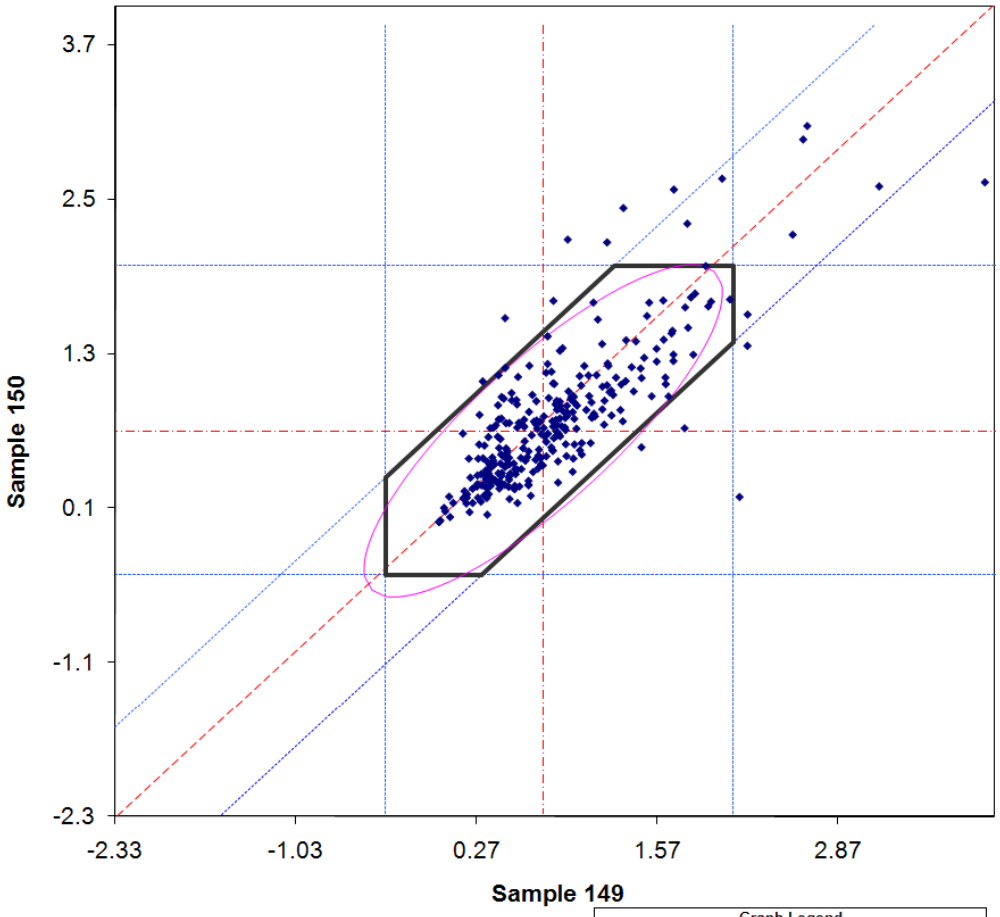
Reproducability (Sample 146)		
1s	d2s	CV%
0.667	1.887	77.8

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

303	Total Laboratories
5	Laboratories Determined to be Invalid
17	Laboratories Determined to be Outliers
281	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
0.747	0.703

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.176	0.498	23.6	25.0

Reproducability (Sample 149)		
1s	d2s	CV%
0.424	1.201	56.8

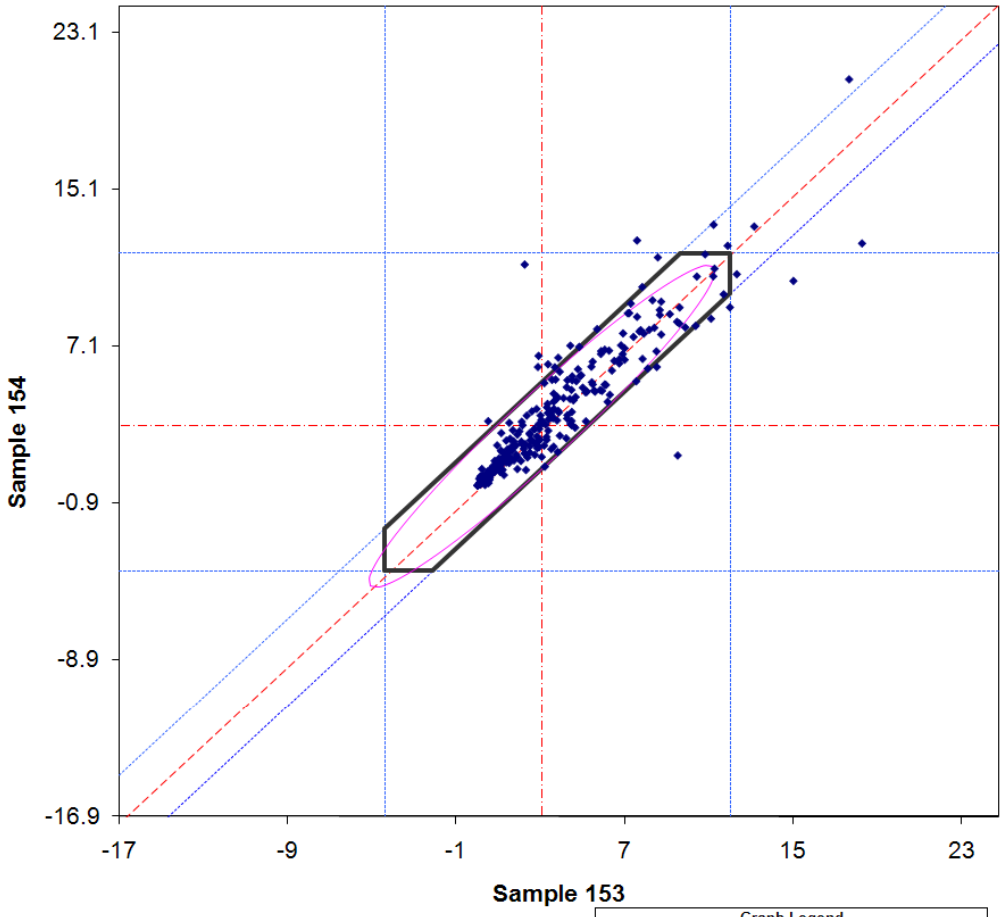
Reproducability (Sample 150)		
1s	d2s	CV%
0.397	1.123	56.5

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

297	Total Laboratories
9	Laboratories Determined to be Invalid
21	Laboratories Determined to be Outliers
267	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
3.066	3.031

Repeatability			
1s	d2s	CV% (153)	CV% (154)
0.522	1.477	17.0	17.2

Reproducability (Sample 153)		
1s	d2s	CV%
2.728	7.716	89.0

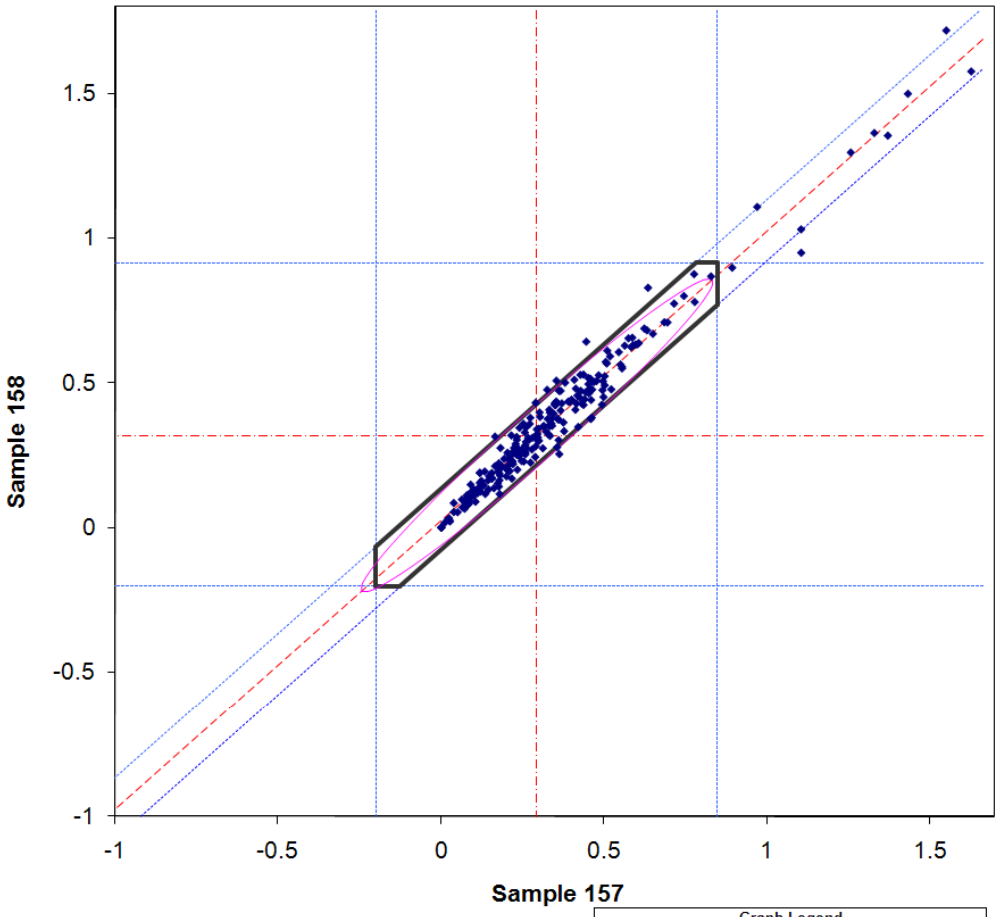
Reproducability (Sample 154)		
1s	d2s	CV%
2.710	7.664	89.4

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

253	Total Laboratories
14	Laboratories Determined to be Invalid
18	Laboratories Determined to be Outliers
221	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.293	0.319

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.026	0.073	8.8	8.1

Reproducability (Sample 157)		
1s	d2s	CV%
0.174	0.493	59.4

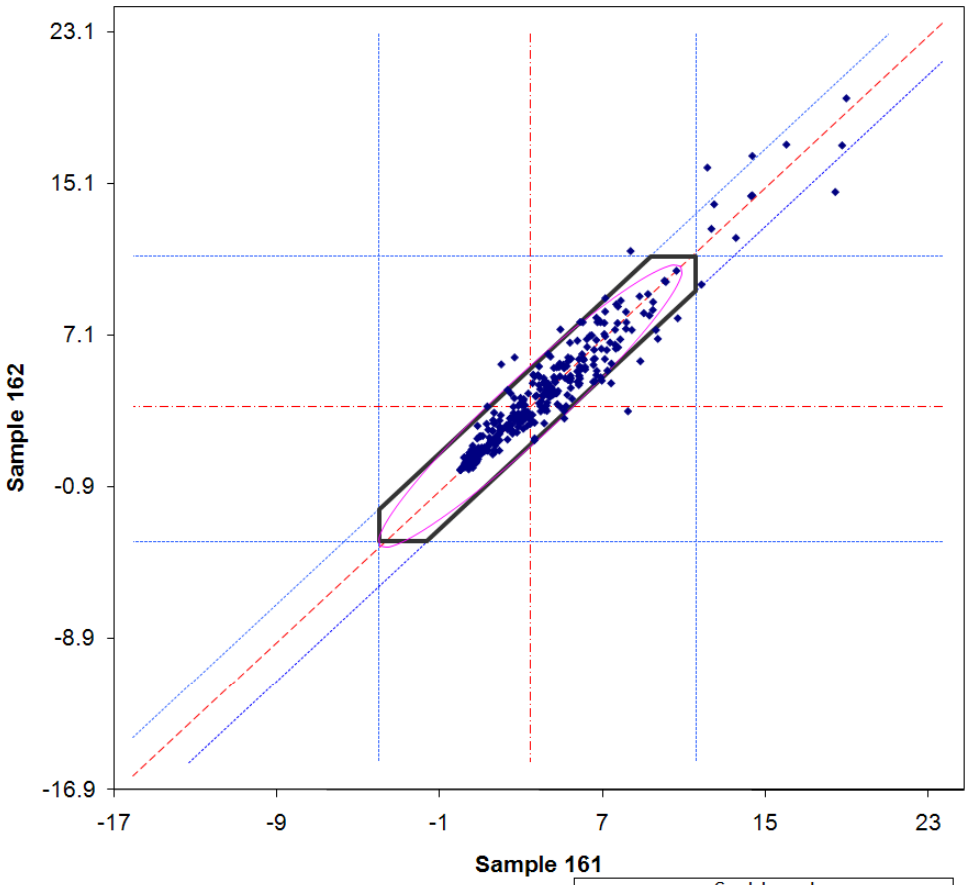
Reproducability (Sample 158)		
1s	d2s	CV%
0.185	0.522	57.9

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Weighted Average Soundness Loss Using Sodium Sulfate, Coarse Aggregate



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

350	Total Laboratories
7	Laboratories Determined to be Invalid
20	Laboratories Determined to be Outliers
323	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
3.450	3.366

Repeatability			
1s	d2s	CV% (161)	CV% (162)
0.512	1.448	14.8	15.2

Reproducability (Sample 161)		
1s	d2s	CV%
2.498	7.065	72.4

Reproducability (Sample 162)		
1s	d2s	CV%
2.429	6.870	72.2

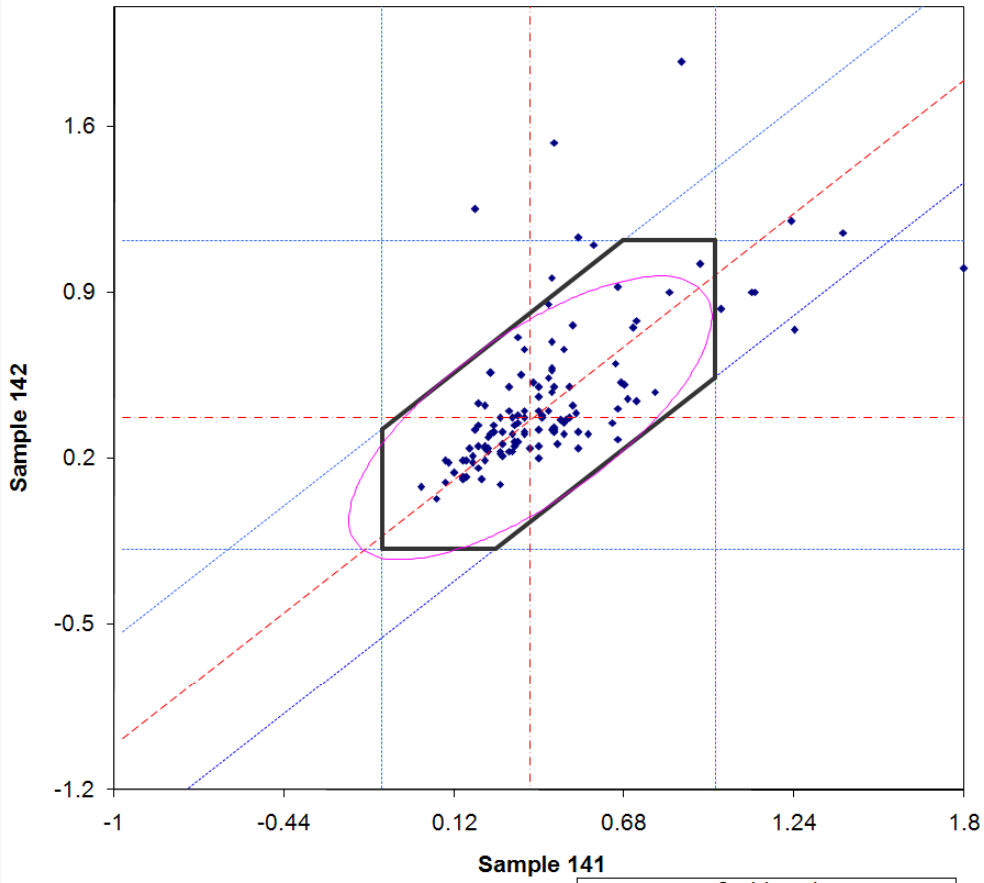
APPENDIX D: SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, COARSE AGGREGATES: 19-MM TO 9.5-MM PASSING 8.0-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

123	Total Laboratories
5	Laboratories Determined to be Invalid
9	Laboratories Determined to be Outliers
109	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.371	0.370

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.106	0.300	28.57	28.62

Reproducability (Sample 141)		
1s	d2s	CV%
0.179	0.506	48.23

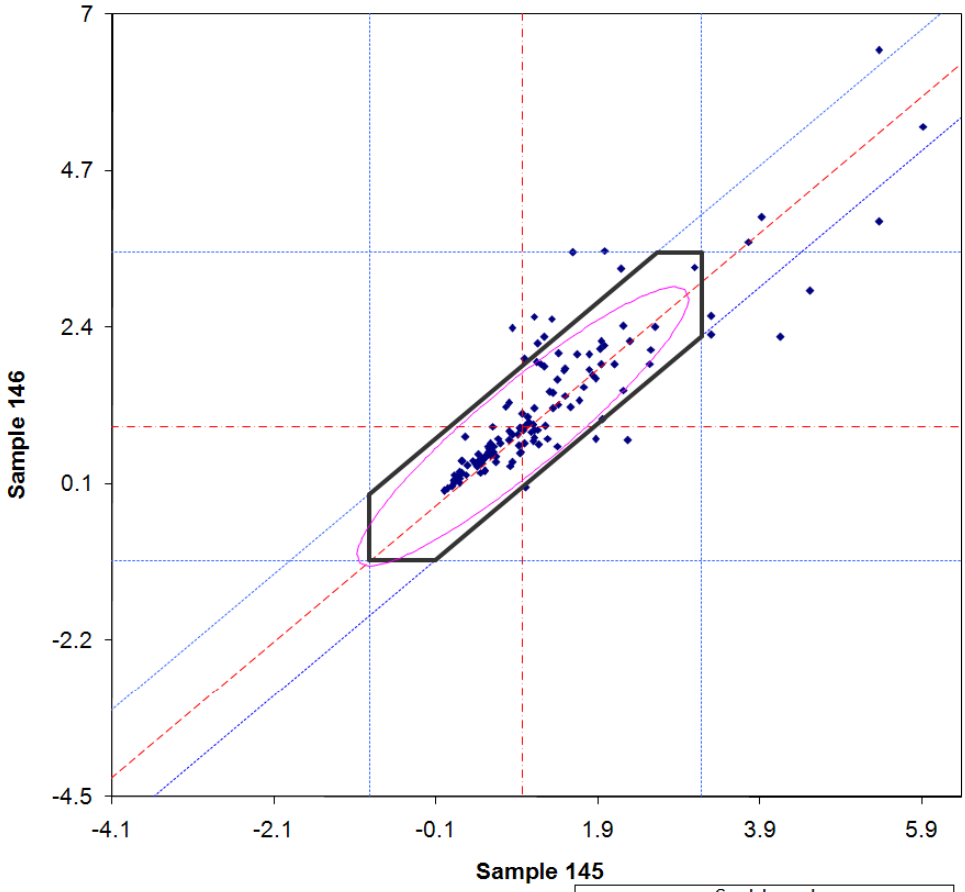
Reproducability (Sample 142)		
1s	d2s	CV%
0.190	0.538	51.37

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

133	Total Laboratories
5	Laboratories Determined to be Invalid
19	Laboratories Determined to be Outliers
109	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
0.972	0.949

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.190	0.537	19.51	19.99

Reproducability (Sample 145)		
1s	d2s	CV%
0.667	1.887	68.61

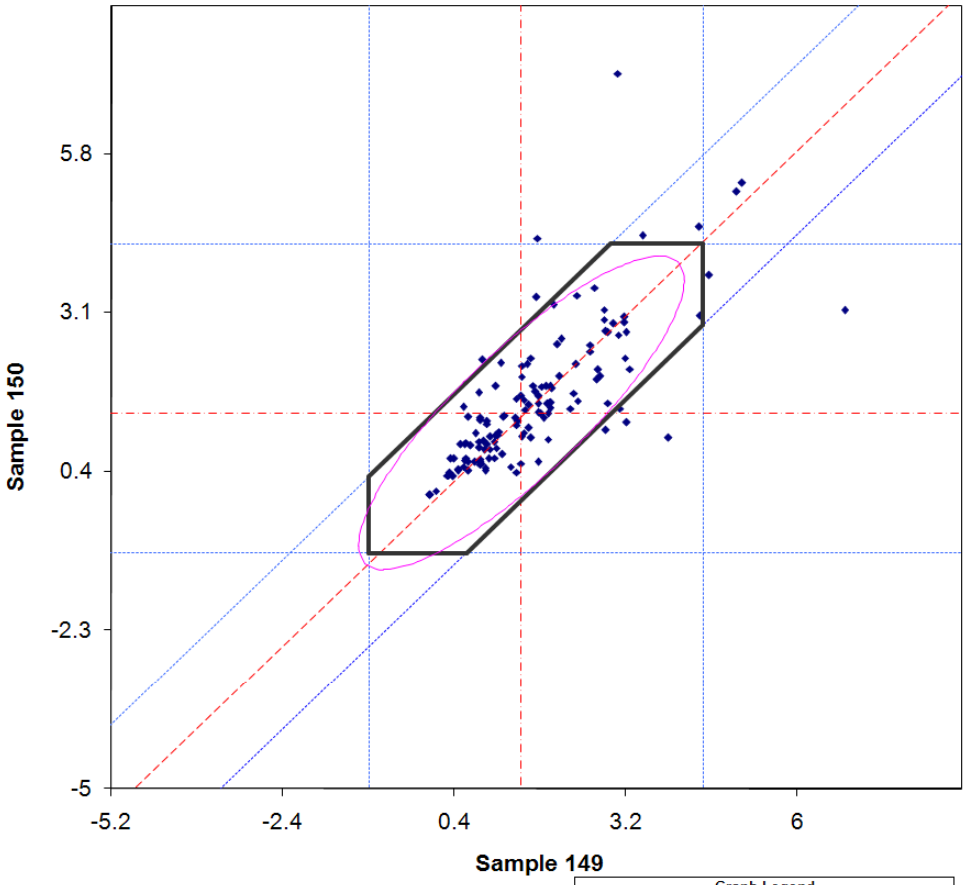
Reproducability (Sample 146)		
1s	d2s	CV%
0.671	1.897	70.64

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

136	Total Laboratories
5	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
121	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
1.498	1.397

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.346	0.977	23.07	24.75

Reproducability (Sample 149)		
1s	d2s	CV%
0.873	2.469	58.27

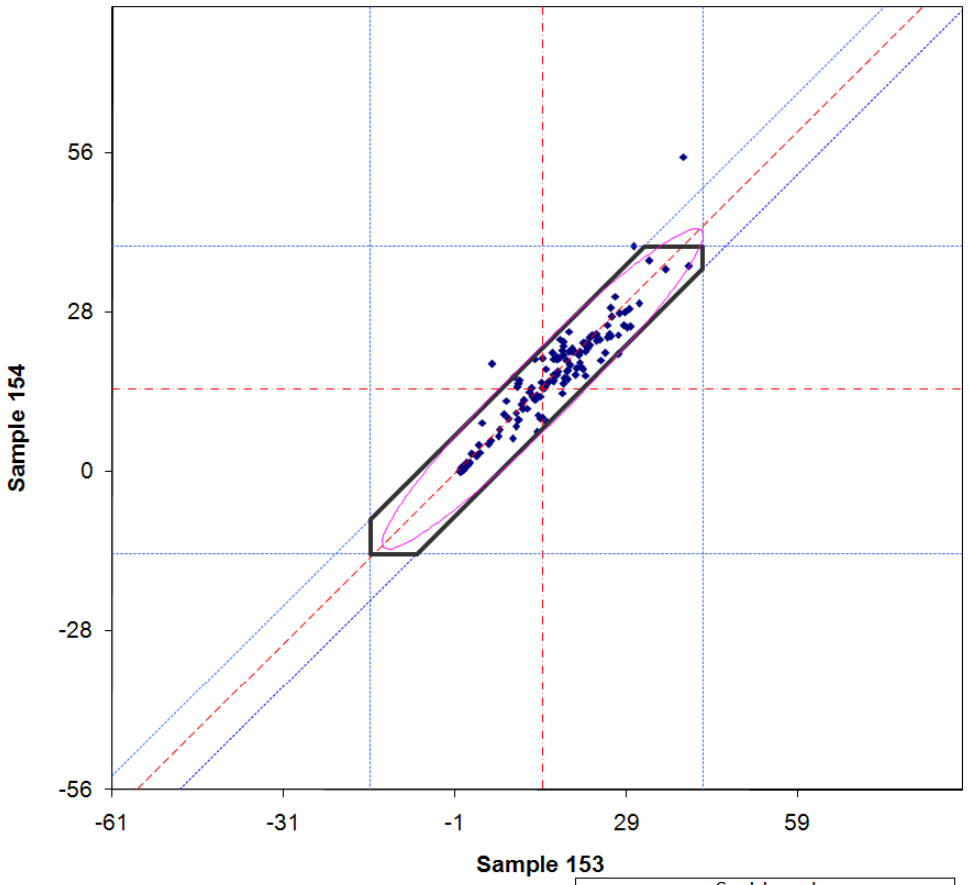
Reproducability (Sample 150)		
1s	d2s	CV%
0.832	2.352	59.55

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

148	Total Laboratories
2	Laboratories Determined to be Invalid
2	Laboratories Determined to be Outliers
144	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
14.362	14.581

Repeatability			
1s	d2s	CV% (153)	CV% (154)
1.820	5.147	12.67	12.48

Reproducability (Sample 153)		
1s	d2s	CV%
9.380	26.531	65.31

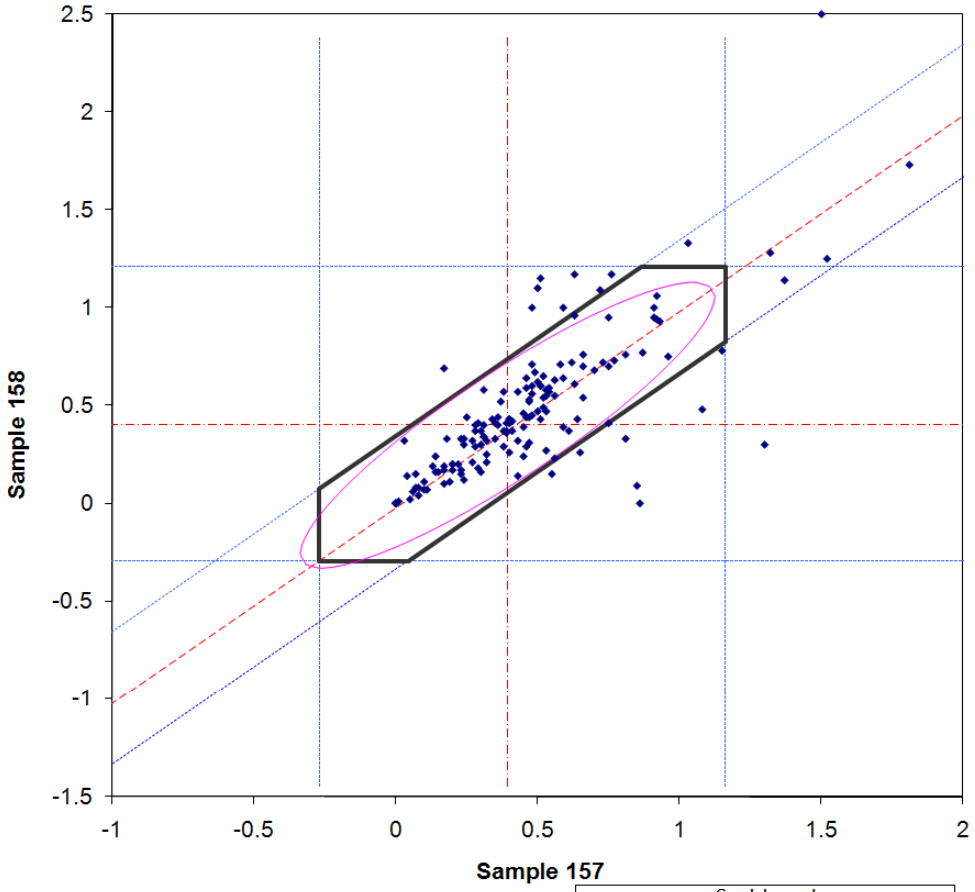
Reproducability (Sample 154)		
1s	d2s	CV%
9.231	26.109	63.31

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

162	Total Laboratories
9	Laboratories Determined to be Invalid
20	Laboratories Determined to be Outliers
133	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.392	0.403

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.077	0.219	19.73	19.22

Reproducability (Sample 157)		
1s	d2s	CV%
0.229	0.647	58.29

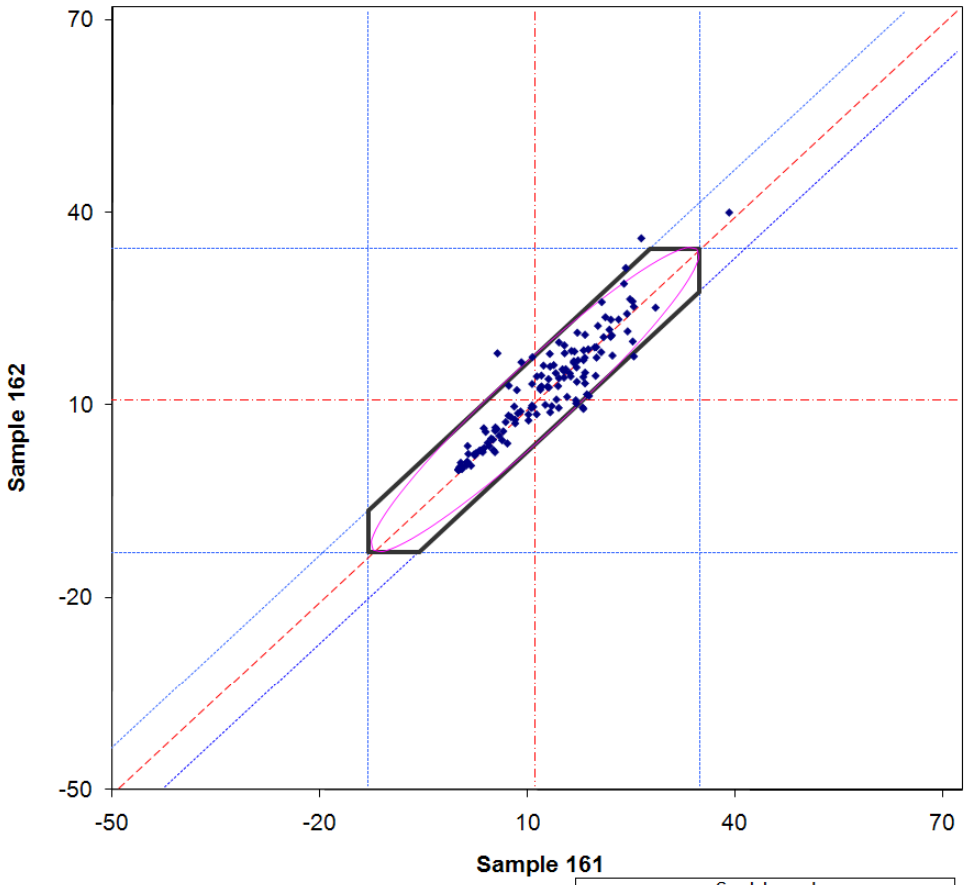
Reproducability (Sample 158)		
1s	d2s	CV%
0.245	0.694	60.92

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Soundness Test Using Magnesium Sulfate, % of 19.0 to 9.5-mm fraction passing 8.0-mm Sieve



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

149	Total Laboratories
1	Laboratories Determined to be Invalid
9	Laboratories Determined to be Outliers
139	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
11.093	10.906

Repeatability			
1s	d2s	CV% (161)	CV% (162)
1.653	4.676	14.90	15.16

Reproducability (Sample 161)		
1s	d2s	CV%
7.814	22.101	70.44

Reproducability (Sample 162)		
1s	d2s	CV%
7.801	22.064	71.53

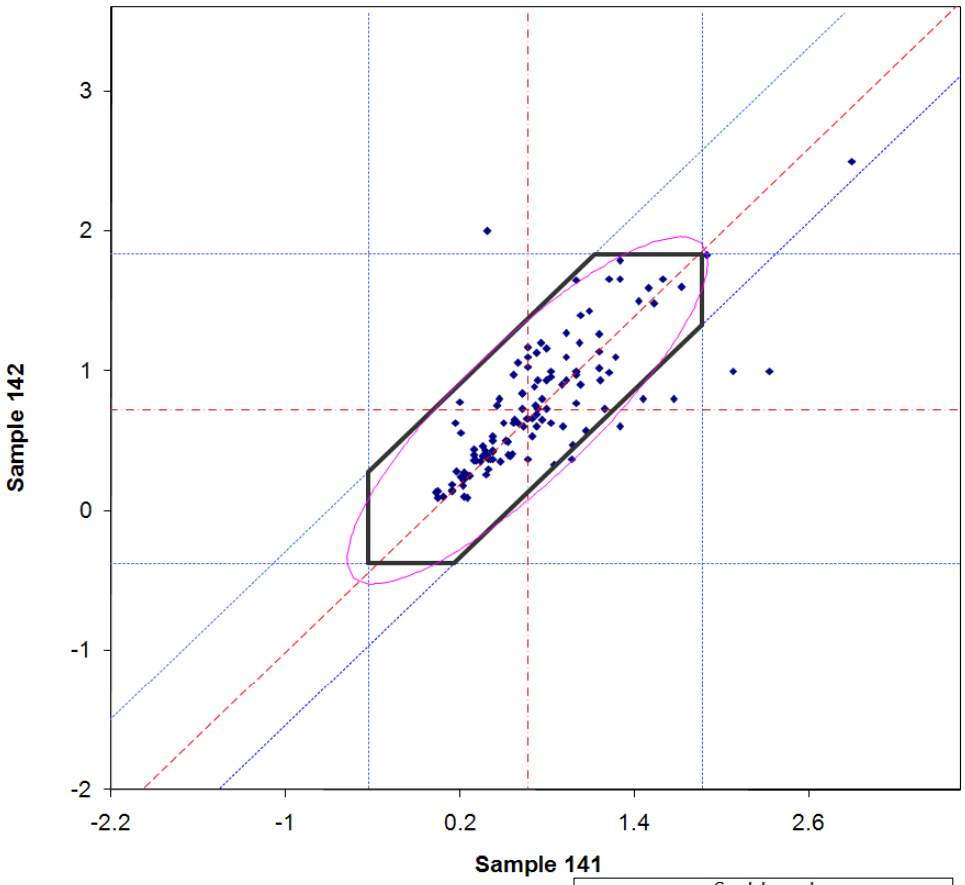
APPENDIX E: SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, COARSE AGGREGATE: 9.5-MM TO 4.75-MM PASSING 4.0-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

123	Total Laboratories
4	Laboratories Determined to be Invalid
6	Laboratories Determined to be Outliers
113	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.665	0.718

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.158	0.446	23.71	21.95

Reproducability (Sample 141)		
1s	d2s	CV%
0.376	1.062	56.46

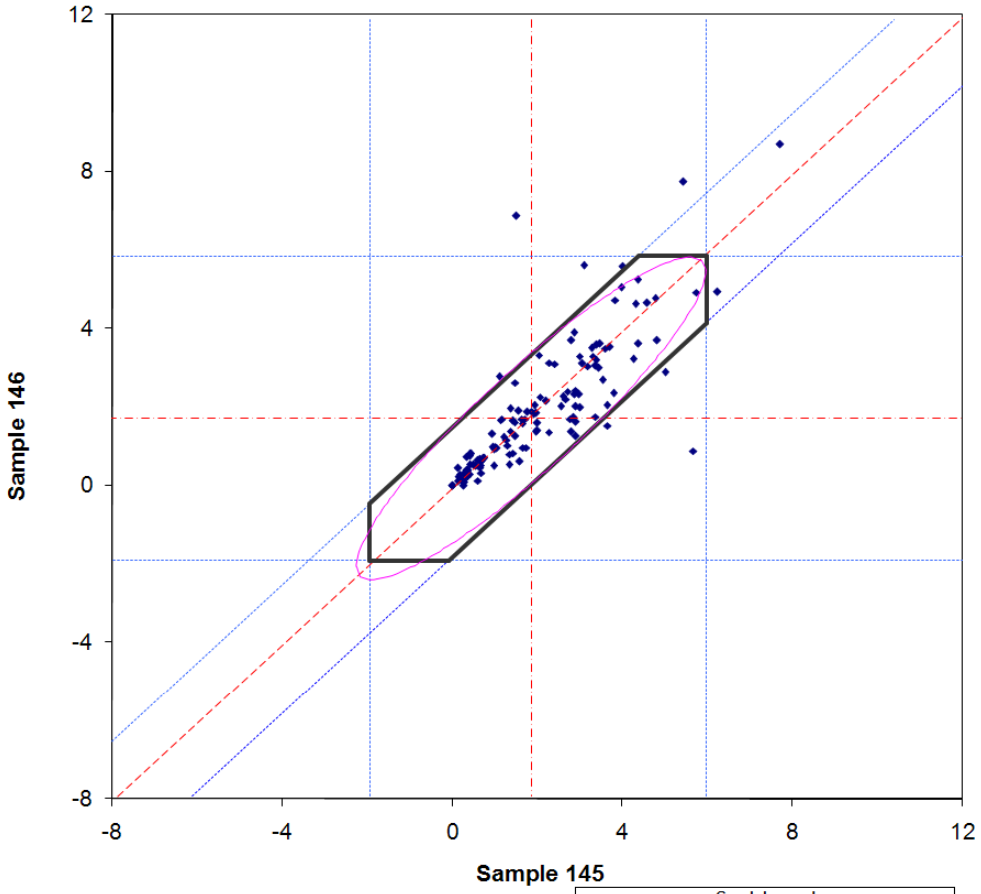
Reproducability (Sample 142)		
1s	d2s	CV%
0.420	1.188	58.46

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

132	Total Laboratories
3	Laboratories Determined to be Invalid
8	Laboratories Determined to be Outliers
121	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
1.849	1.714

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.401	1.133	21.67	23.38

Reproducability (Sample 145)		
1s	d2s	CV%
1.352	3.824	73.12

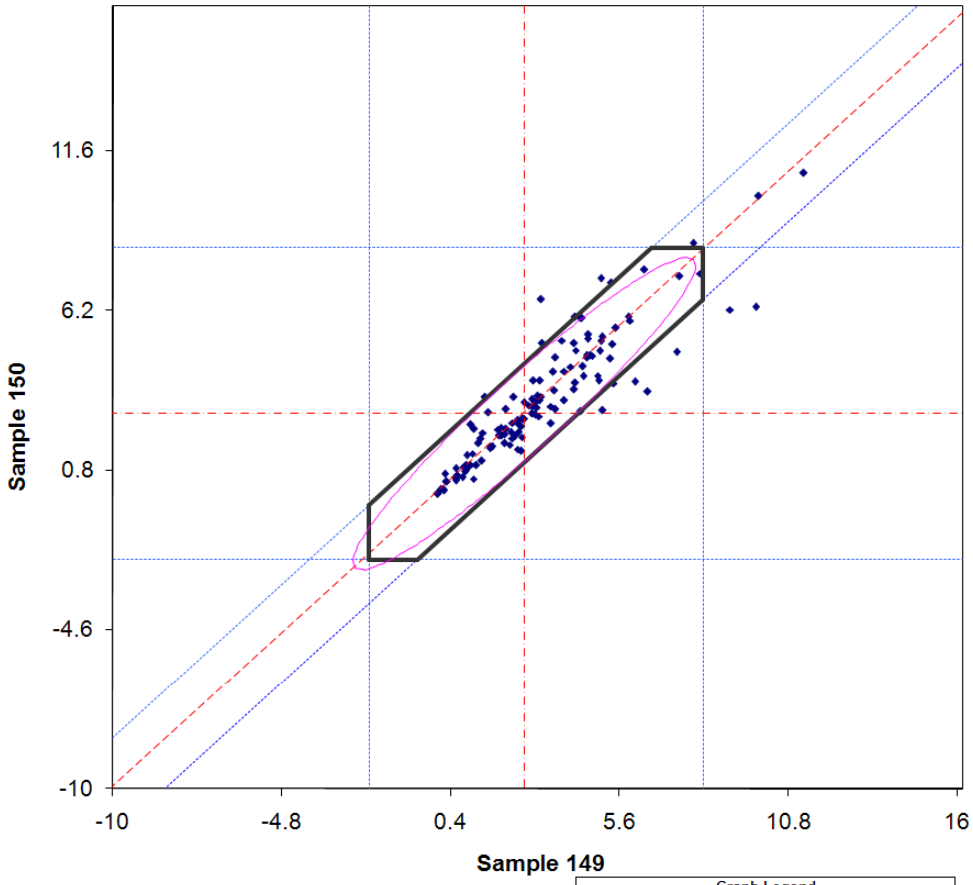
Reproducability (Sample 146)		
1s	d2s	CV%
1.328	3.757	77.51

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

135	Total Laboratories
3	Laboratories Determined to be Invalid
14	Laboratories Determined to be Outliers
118	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
2.673	2.713

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.386	1.092	14.44	14.23

Reproducability (Sample 149)		
1s	d2s	CV%
1.719	4.862	64.30

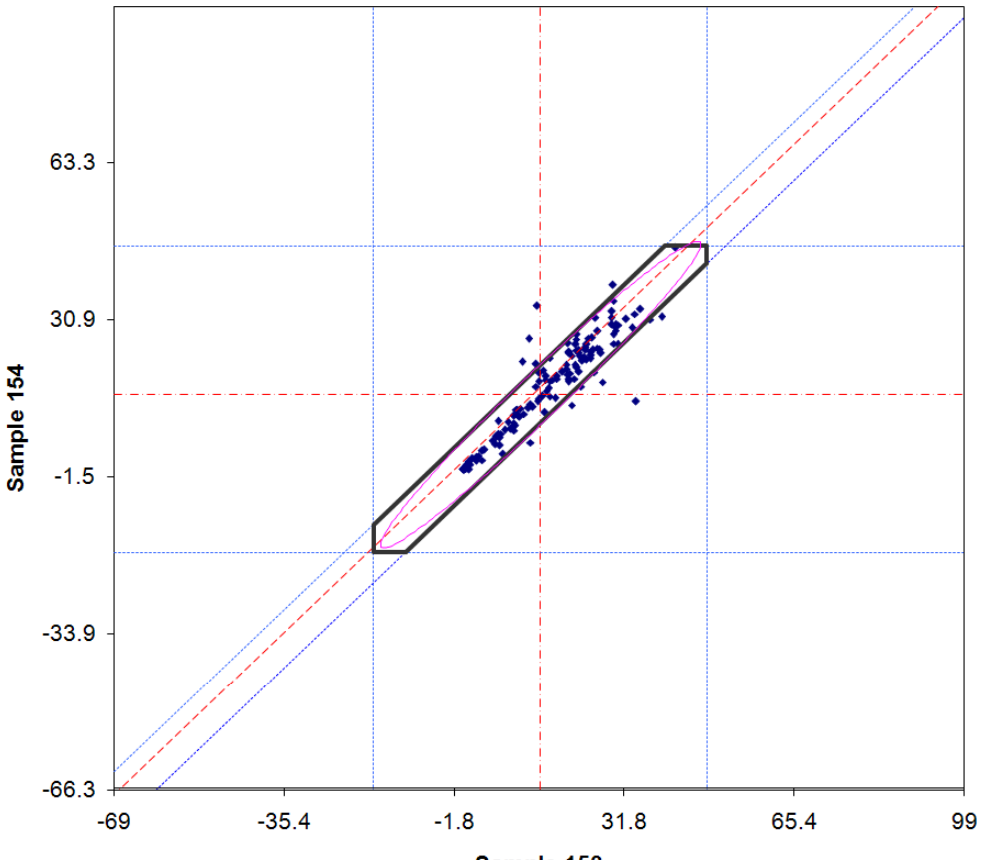
Reproducability (Sample 150)		
1s	d2s	CV%
1.760	4.977	64.86

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

147	Total Laboratories
3	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
134	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
15.202	15.476

Repeatability			
1s	d2s	CV% (153)	CV% (154)
1.475	4.171	9.70	9.53

Reproducability (Sample 153)		
1s	d2s	CV%
10.381	29.363	68.29

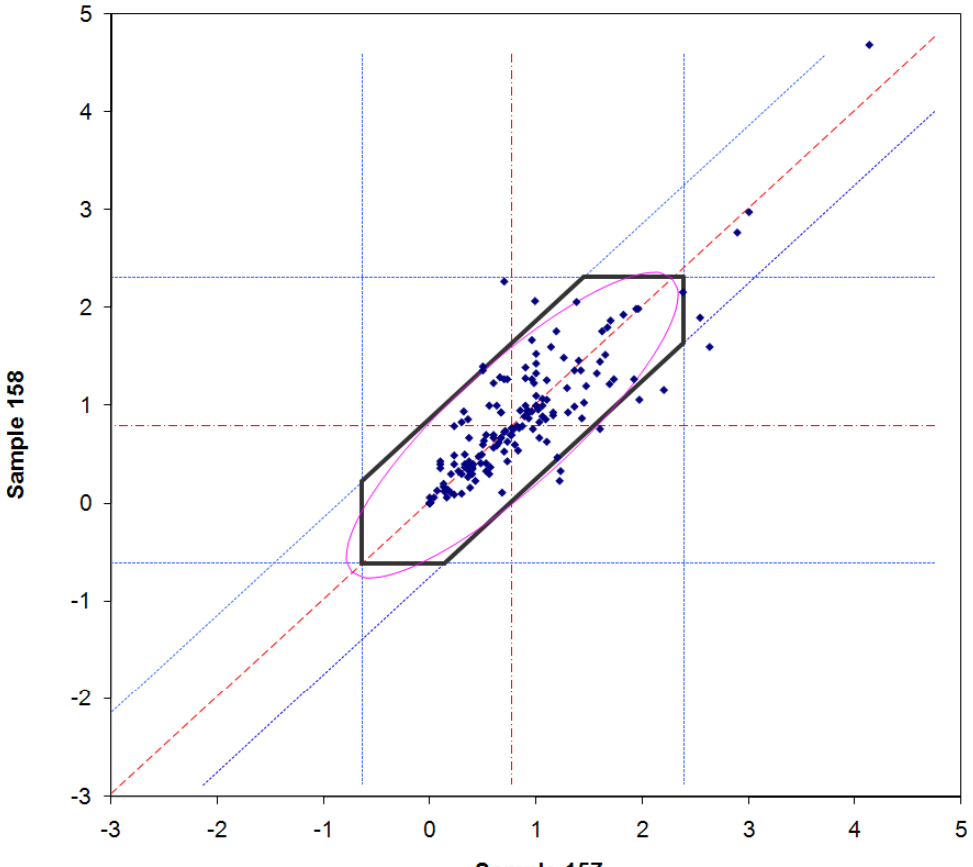
Reproducability (Sample 154)		
1s	d2s	CV%
10.674	30.192	68.97

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

162	Total Laboratories
5	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
145	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.769	0.800

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.196	0.555	25.53	24.53

Reproducability (Sample 157)		
1s	d2s	CV%
0.496	1.404	64.52

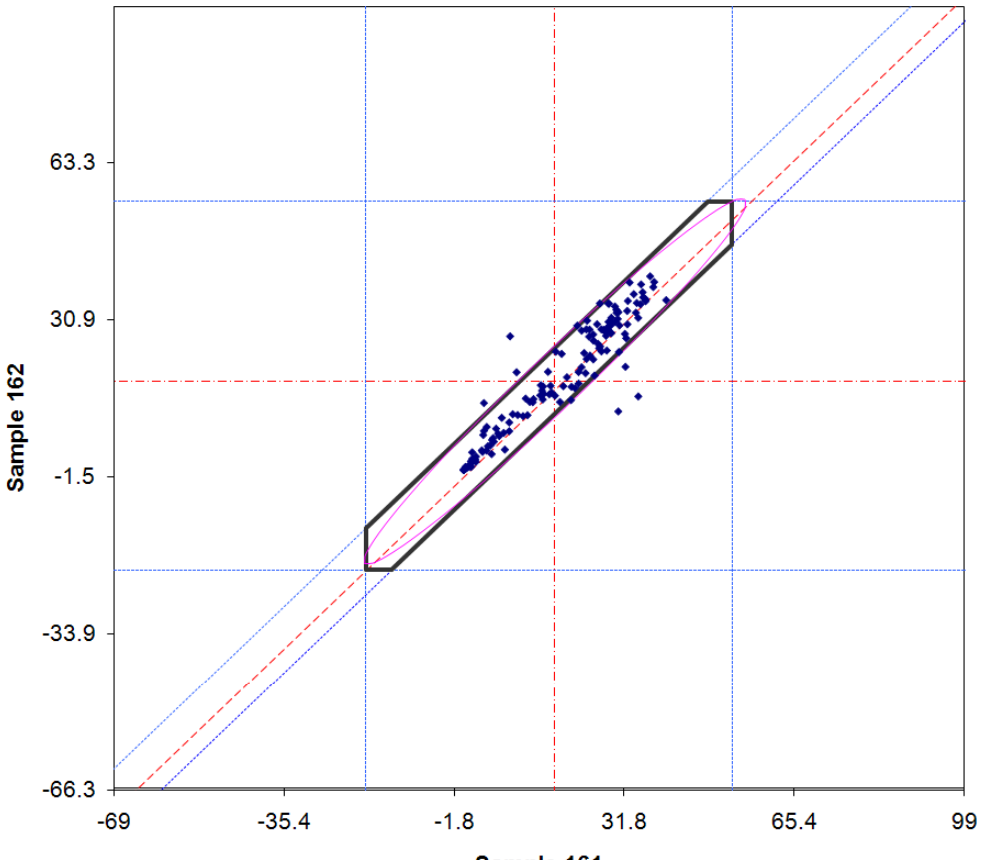
Reproducability (Sample 158)		
1s	d2s	CV%
0.507	1.433	63.30

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Soundness Test Using Magnesium Sulfate, % of 9.5 to 4.75-mm fraction passing 4.0-mm Sieve



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

149	Total Laboratories
3	Laboratories Determined to be Invalid
6	Laboratories Determined to be Outliers
140	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
17.969	18.174

Repeatability			
1s	d2s	CV% (161)	CV% (162)
1.745	4.936	9.71	9.60

Reproducability (Sample 161)		
1s	d2s	CV%
12.447	35.204	69.27

Reproducability (Sample 162)		
1s	d2s	CV%
12.621	35.697	69.44

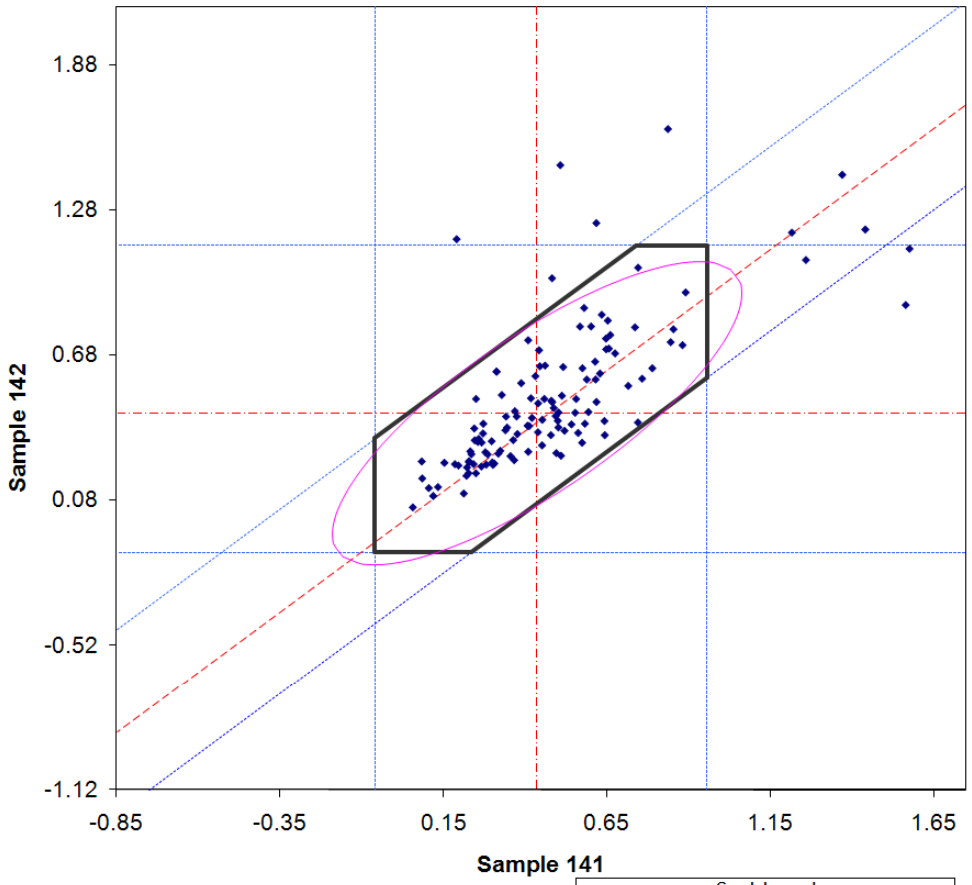
APPENDIX F: WEIGHTED AVERAGE SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, COARSE AGGREGATE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 141 and 142

Weighted Average Soundness Loss Using Magnesium Sulfate, Coarse Aggregate



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 Samples 141 and 142
Final Report Issued November 2003

Participation:

125	Total Laboratories
6	Laboratories Determined to be Invalid
6	Laboratories Determined to be Outliers
113	Total Laboratorires Included in Analysis

Average Results	
Sample 141 Average	Sample 142 Average
0.436	0.440

Repeatability			
1s	d2s	CV% (141)	CV% (142)
0.095	0.268	21.7	21.5

Reproducability (Sample 141)		
1s	d2s	CV%
0.190	0.537	43.5

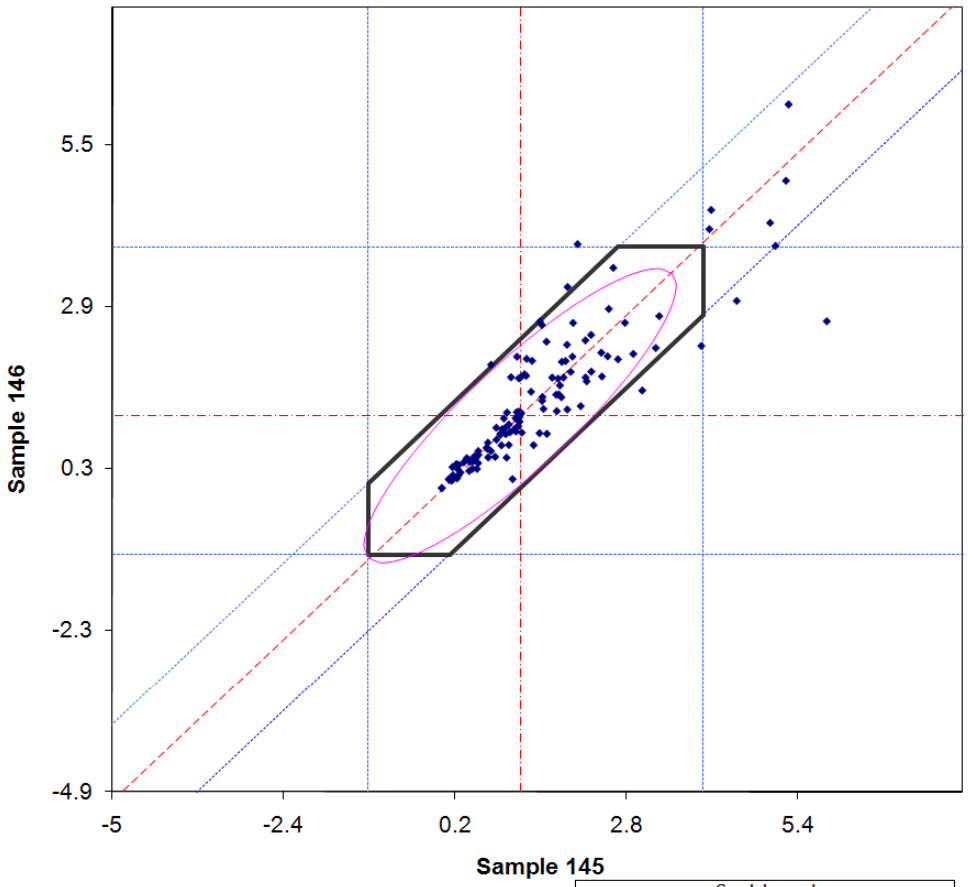
Reproducability (Sample 142)		
1s	d2s	CV%
0.205	0.581	46.7

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 145 and 146

Weighted Average Soundness Test Using Magnesium Sulfate, Coarse Aggregate



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 Samples 145 and 146
Final Report Issued November 2004

Participation:

132	Total Laboratories
2	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
118	Total Laboratorires Included in Analysis

Average Results	
Sample 145 Average	Sample 146 Average
1.184	1.158

Repeatability			
1s	d2s	CV% (145)	CV% (146)
0.272	0.768	22.9	23.5

Reproducability (Sample 145)		
1s	d2s	CV%
0.751	2.124	63.4

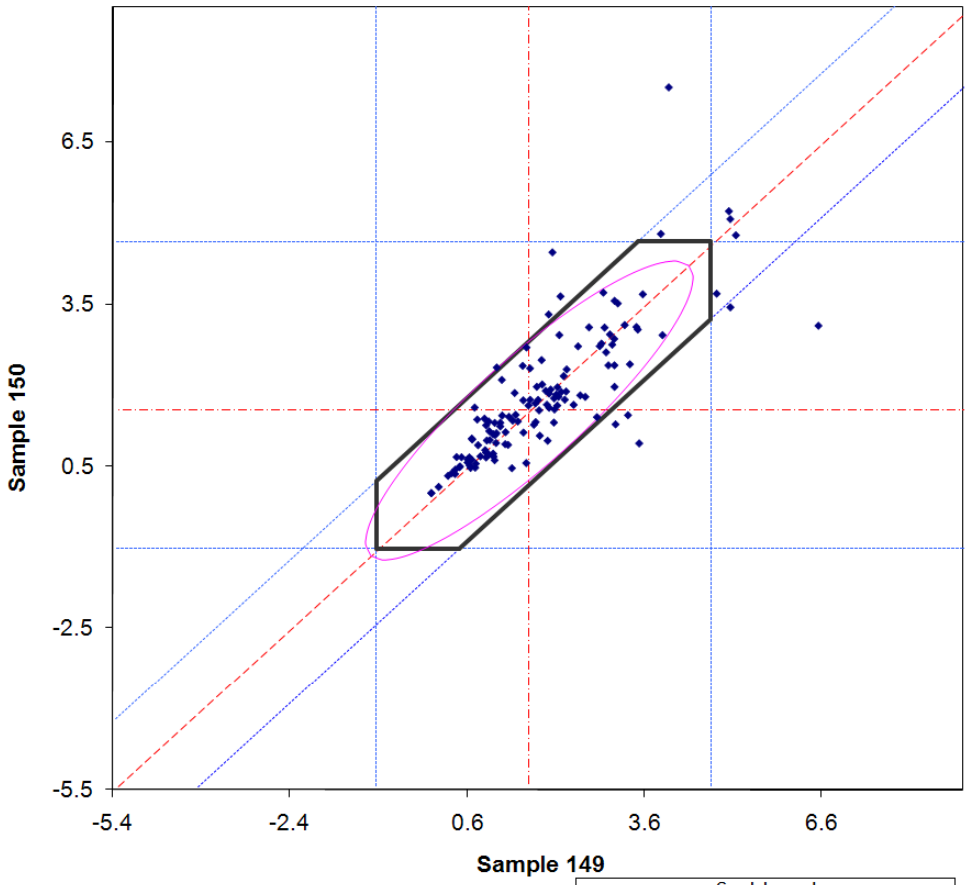
Reproducability (Sample 146)		
1s	d2s	CV%
0.773	2.187	66.8

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 149 and 150

Weighted Average Soundness Loss Using Magnesium Sulfate, Coarse Aggregate



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 Samples 149 and 150
Final Report Issued November 2005

Participation:

133	Total Laboratories
4	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
117	Total Laboratorires Included in Analysis

Average Results	
Sample 149 Average	Sample 150 Average
1.649	1.546

Repeatability			
1s	d2s	CV% (149)	CV% (150)
0.311	0.881	18.9	20.2

Reproducability (Sample 149)		
1s	d2s	CV%
0.914	2.585	55.4

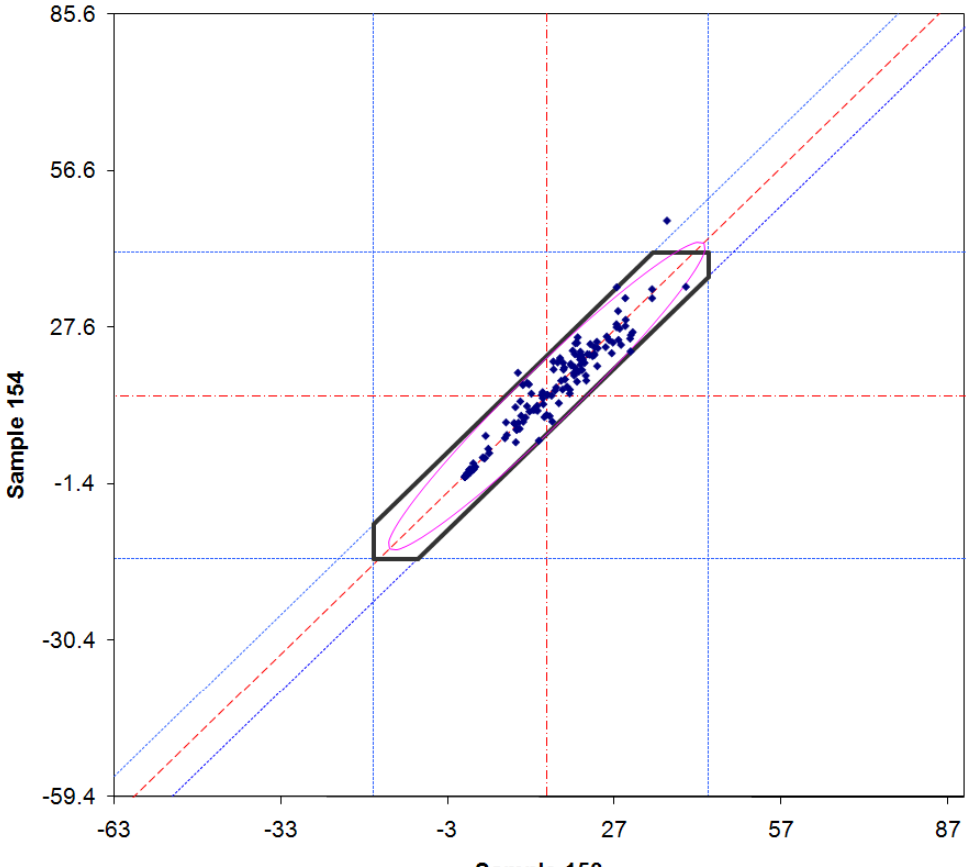
Reproducability (Sample 150)		
1s	d2s	CV%
0.876	2.479	56.7

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 153 and 154

Weighted Average Soundness Loss Using Magnesium Sulfate, Coarse Aggregate



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 Samples 153 and 154
Final Report Issued November 2006

Participation:

147	Total Laboratories
0	Laboratories Determined to be Invalid
3	Laboratories Determined to be Outliers
144	Total Laboratorires Included in Analysis

Average Results	
Sample 153 Average	Sample 154 Average
14.76	14.91

Repeatability			
1s	d2s	CV% (153)	CV% (154)
1.674	4.736	11.3	11.2

Reproducability (Sample 153)		
1s	d2s	CV%
9.486	26.831	64.3

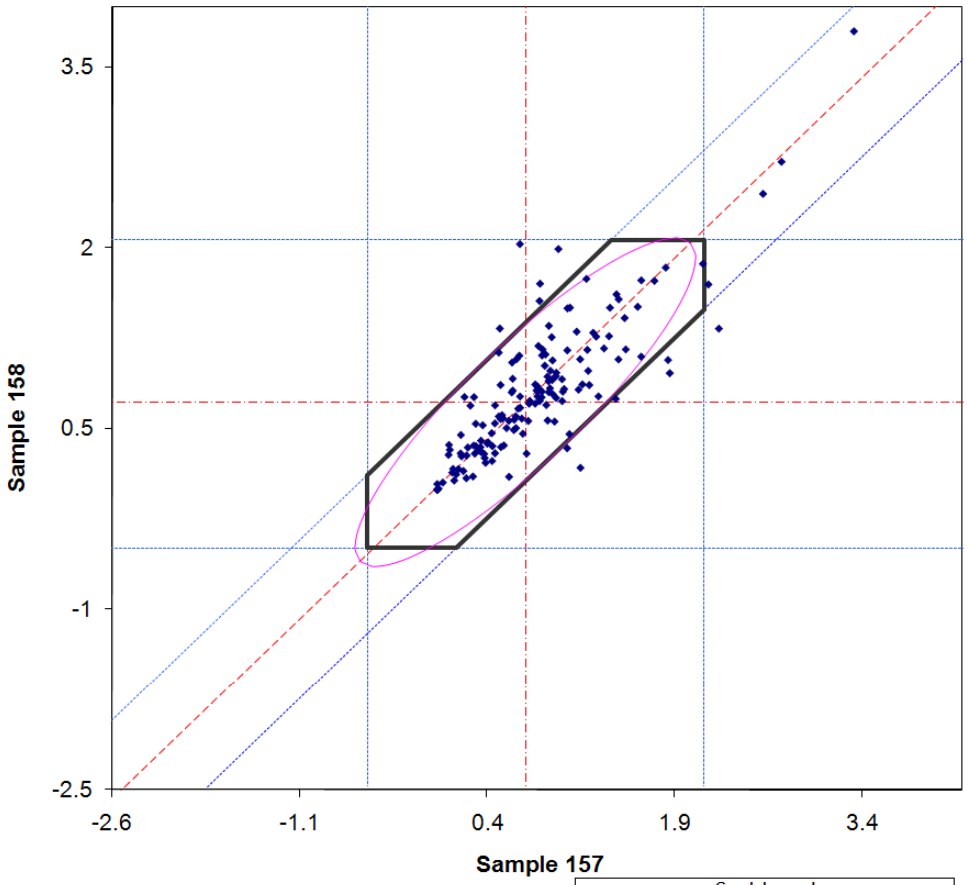
Reproducability (Sample 154)		
1s	d2s	CV%
9.351	26.448	62.7

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 157 and 158

Weighted Average Soundness Loss Using Magnesium Sulfate, Coarse Aggregate



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 Samples 157 and 158
Final Report Issued November 2007

Participation:

162	Total Laboratories
6	Laboratories Determined to be Invalid
13	Laboratories Determined to be Outliers
143	Total Laboratorires Included in Analysis

Average Results	
Sample 157 Average	Sample 158 Average
0.70	0.72

Repeatability			
1s	d2s	CV% (157)	CV% (158)
0.157	0.445	22.3	21.7

Reproducability (Sample 157)		
1s	d2s	CV%
0.439	1.242	62.3

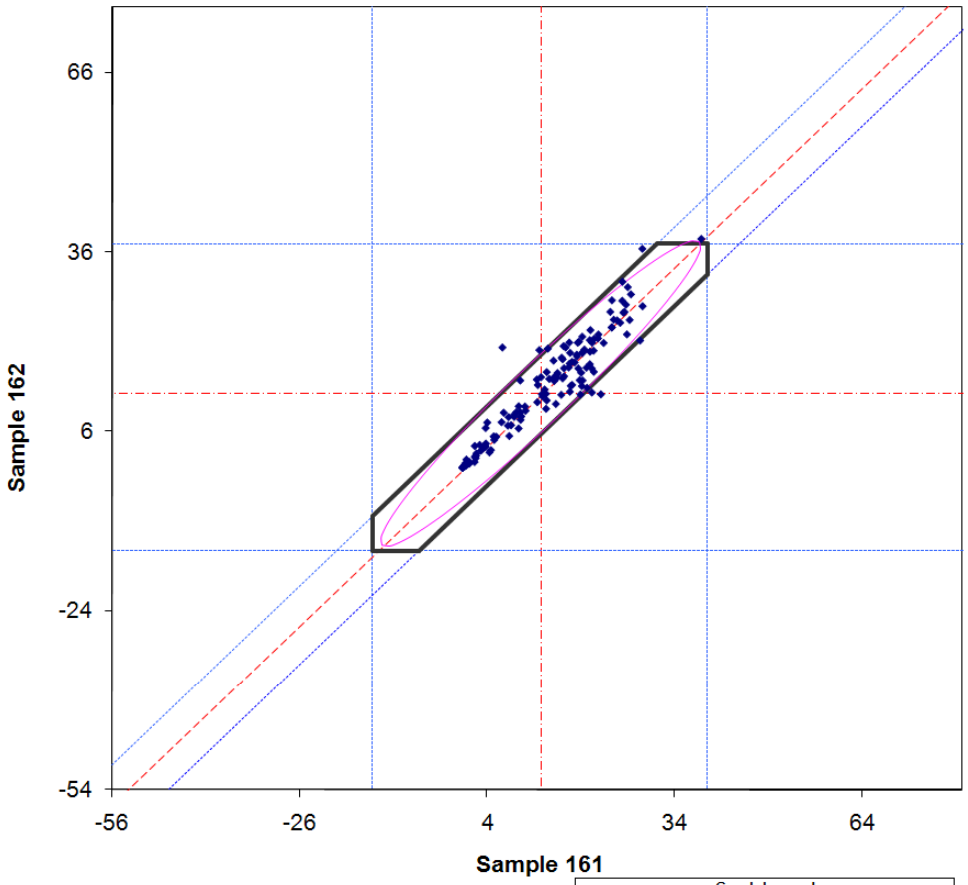
Reproducability (Sample 158)		
1s	d2s	CV%
0.441	1.248	61.0

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 161 and 162

Weighted Average Soundness Loss Using Magnesium Sulfate, Coarse Aggregate



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 Samples 161 and 162
Final Report Issued November 2008

Participation:

149	Total Laboratories
1	Laboratories Determined to be Invalid
6	Laboratories Determined to be Outliers
142	Total Laboratorires Included in Analysis

Average Results	
Sample 161 Average	Sample 162 Average
12.55	12.48

Repeatability			
1s	d2s	CV% (161)	CV% (162)
1.565	4.427	12.5	12.5

Reproducability (Sample 161)		
1s	d2s	CV%
8.404	23.771	67.0

Reproducability (Sample 162)		
1s	d2s	CV%
8.510	24.069	68.2

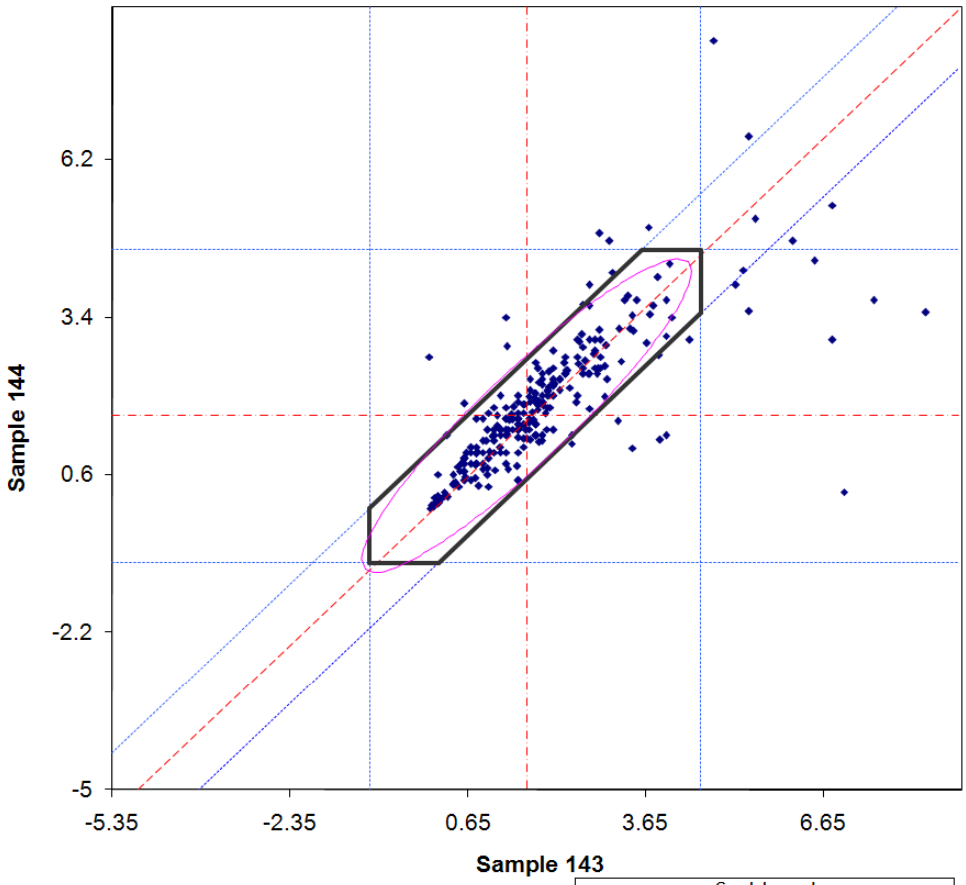
APPENDIX G: SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, MATERIAL FINER THAN 1.18-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18-mm Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

266	Total Laboratories
13	Laboratories Determined to be Invalid
19	Laboratories Determined to be Outliers
234	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
1.643	1.652

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.259	0.732	15.74	15.66

Reproducability (Sample 143)		
1s	d2s	CV%
0.916	2.592	55.77

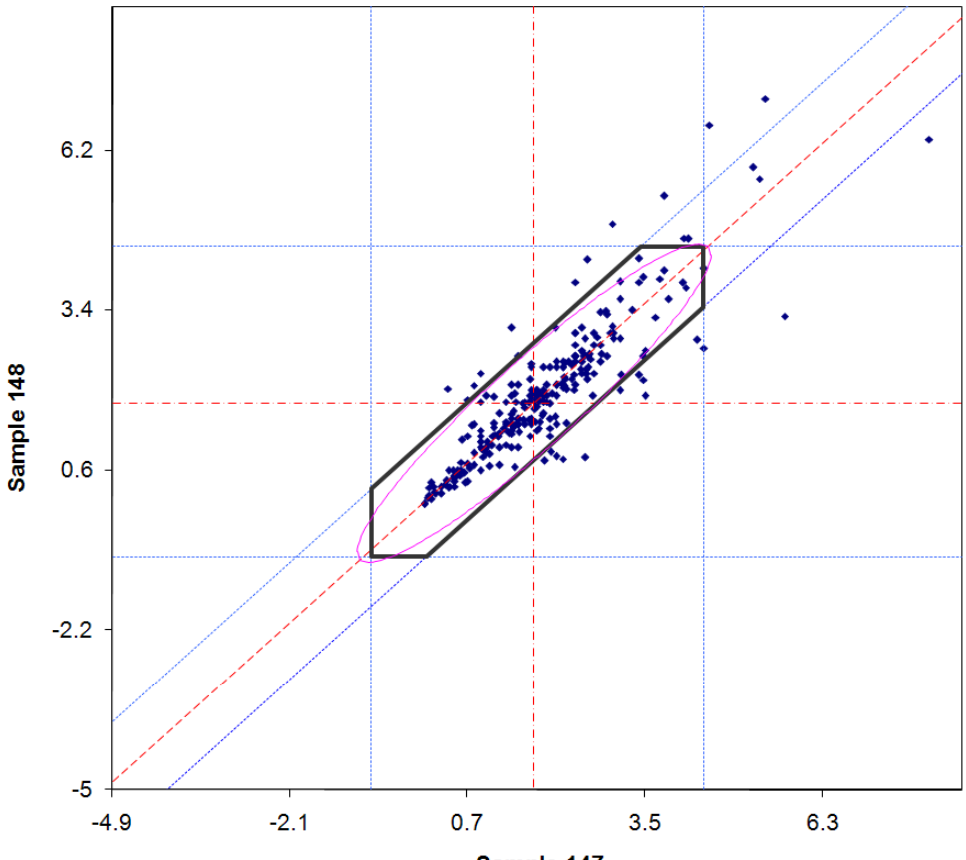
Reproducability (Sample 144)		
1s	d2s	CV%
0.902	2.552	54.63

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

263	Total Laboratories
9	Laboratories Determined to be Invalid
24	Laboratories Determined to be Outliers
230	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
1.748	1.775

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.236	0.669	13.52	13.32

Reproducability (Sample 147)		
1s	d2s	CV%
0.899	2.543	51.44

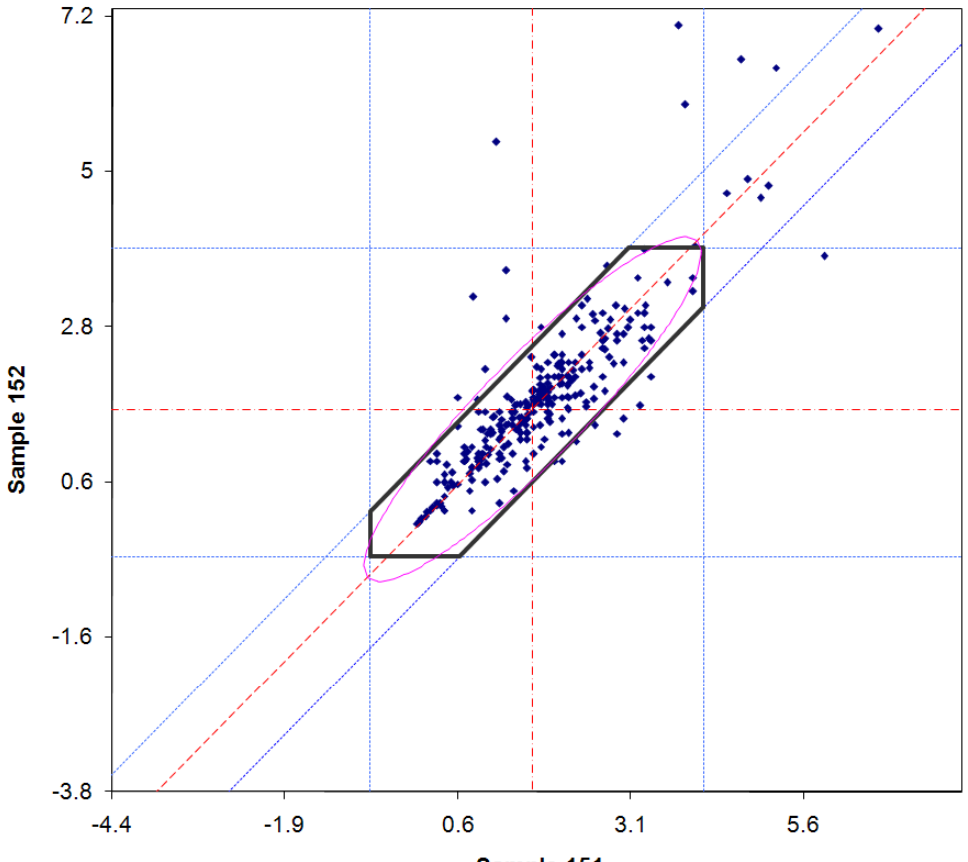
Reproducability (Sample 148)		
1s	d2s	CV%
0.927	2.623	52.25

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

290	Total Laboratories
12	Laboratories Determined to be Invalid
19	Laboratories Determined to be Outliers
259	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
1.681	1.631

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.242	0.686	14.43	14.86

Reproducability (Sample 151)		
1s	d2s	CV%
0.822	2.324	48.89

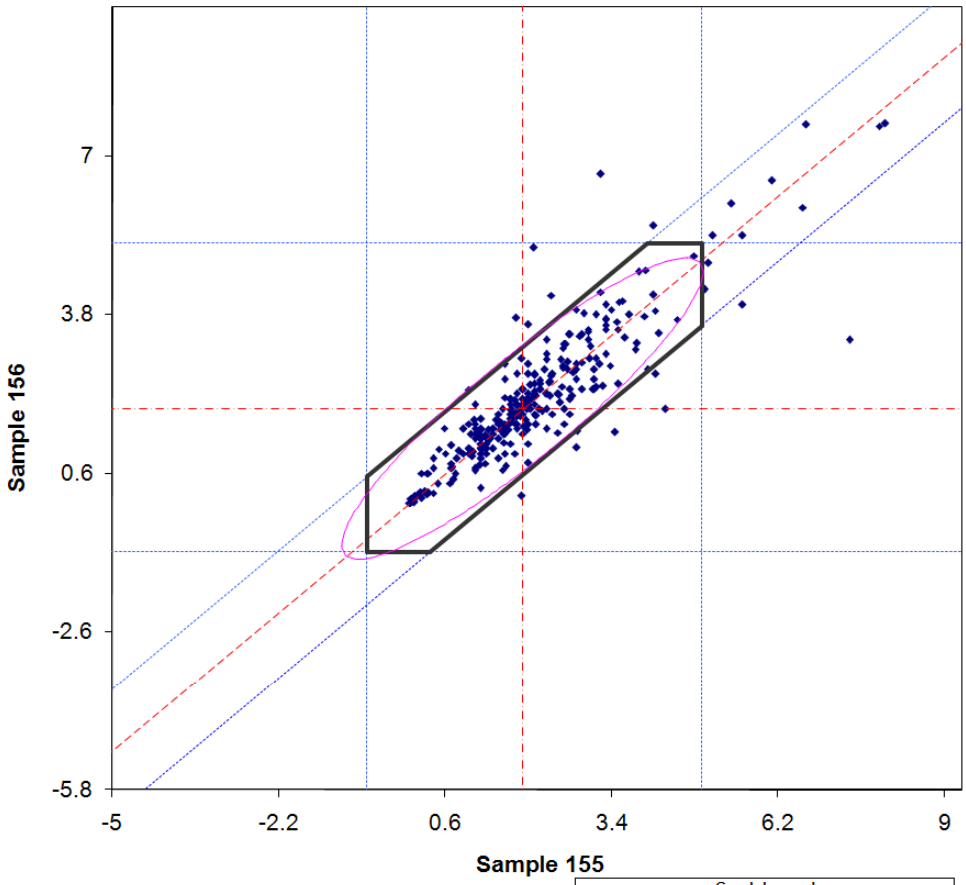
Reproducability (Sample 152)		
1s	d2s	CV%
0.768	2.173	47.10

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

300	Total Laboratories
9	Laboratories Determined to be Invalid
19	Laboratories Determined to be Outliers
272	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
1.898	1.908

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.307	0.869	16.19	16.10

Reproducability (Sample 155)		
1s	d2s	CV%
0.966	2.733	50.92

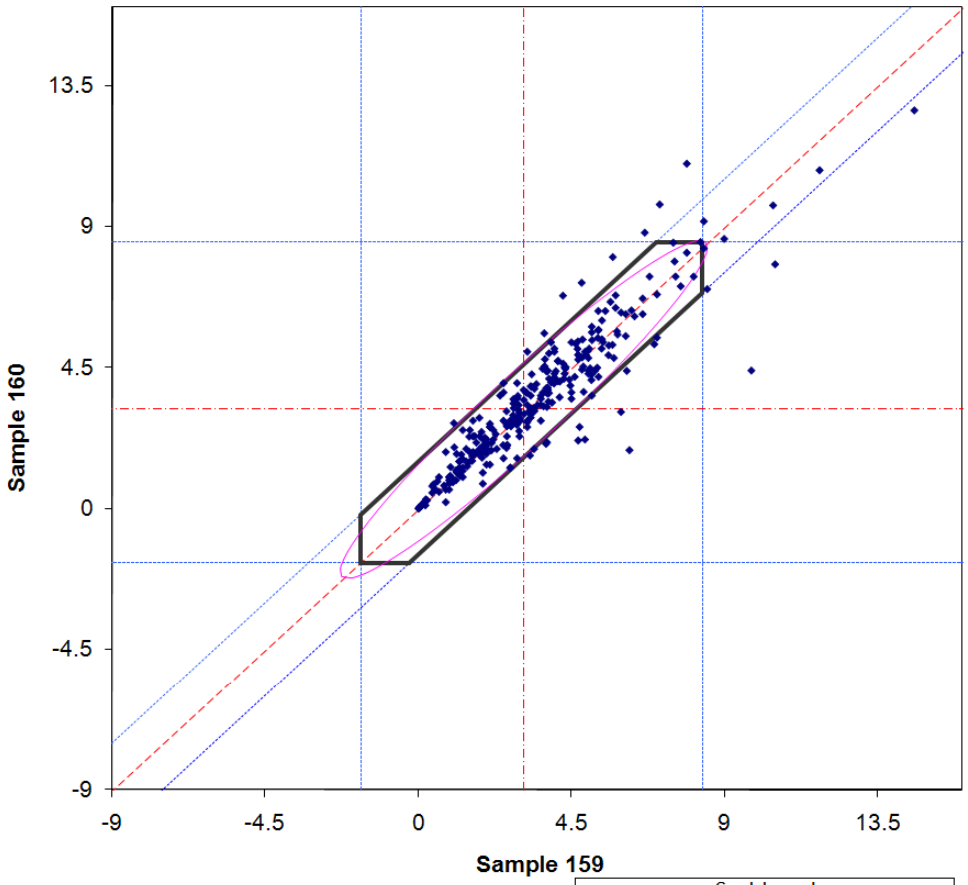
Reproducability (Sample 156)		
1s	d2s	CV%
1.013	2.865	53.07

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

320	Total Laboratories
11	Laboratories Determined to be Invalid
26	Laboratories Determined to be Outliers
283	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
3.103	3.173

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.356	1.007	11.48	11.22

Reproducability (Sample 159)		
1s	d2s	CV%
1.768	5.001	56.97

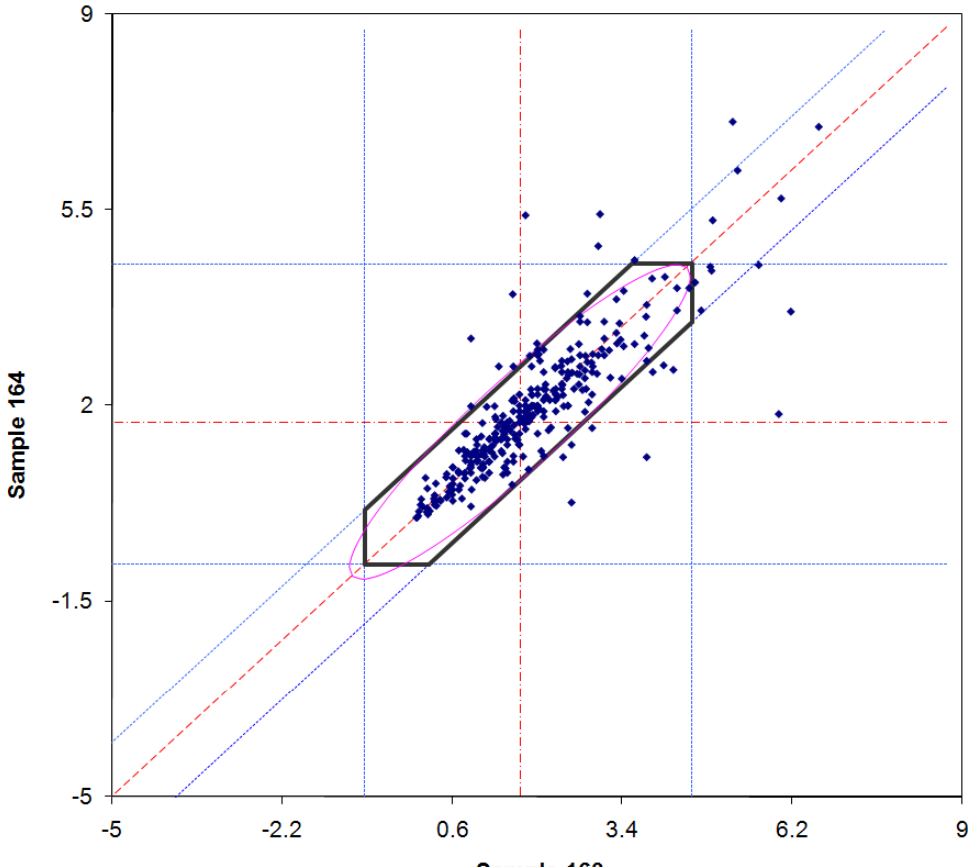
Reproducability (Sample 160)		
1s	d2s	CV%
1.796	5.079	56.59

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Sodium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

330	Total Laboratories
16	Laboratories Determined to be Invalid
24	Laboratories Determined to be Outliers
290	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
1.714	1.711

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.253	0.715	14.75	14.77

Reproducability (Sample 163)		
1s	d2s	CV%
0.920	2.601	53.66

Reproducability (Sample 164)		
1s	d2s	CV%
0.918	2.597	53.67

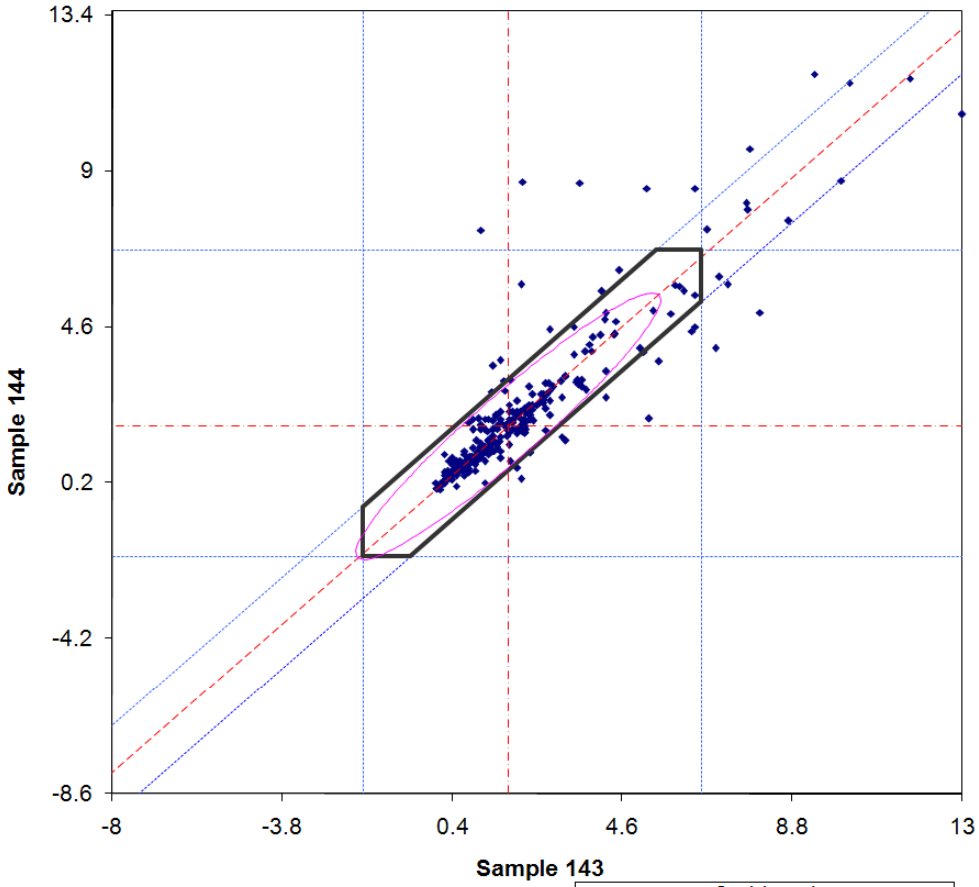
APPENDIX H: SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, MATERIAL FINER THAN 600-μM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

266	Total Laboratories
16	Laboratories Determined to be Invalid
29	Laboratories Determined to be Outliers
221	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
2	2

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.3	0.8	15.7	15.6

Reproducability (Sample 143)		
1s	d2s	CV%
1.3	3.6	71.3

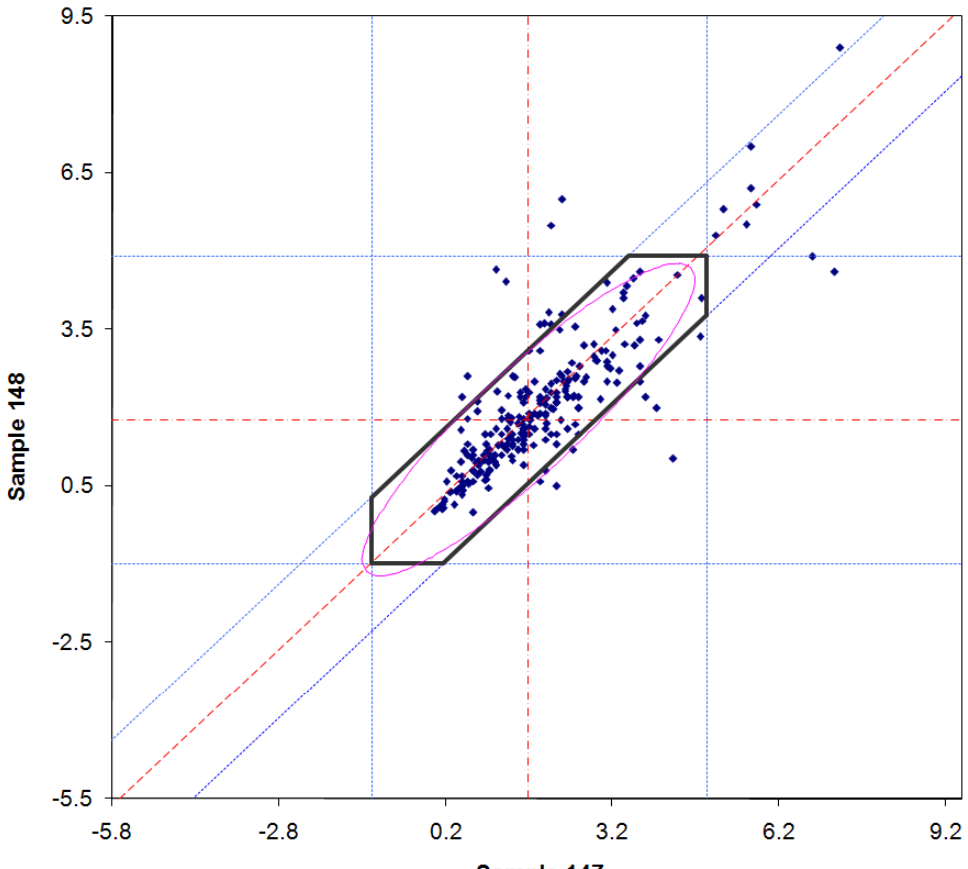
Reproducability (Sample 144)		
1s	d2s	CV%
1.2	3.4	68.0

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

263	Total Laboratories
14	Laboratories Determined to be Invalid
22	Laboratories Determined to be Outliers
227	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
1.690	1.776

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.318	0.899	18.81	17.90

Reproducability (Sample 147)		
1s	d2s	CV%
0.961	2.719	56.90

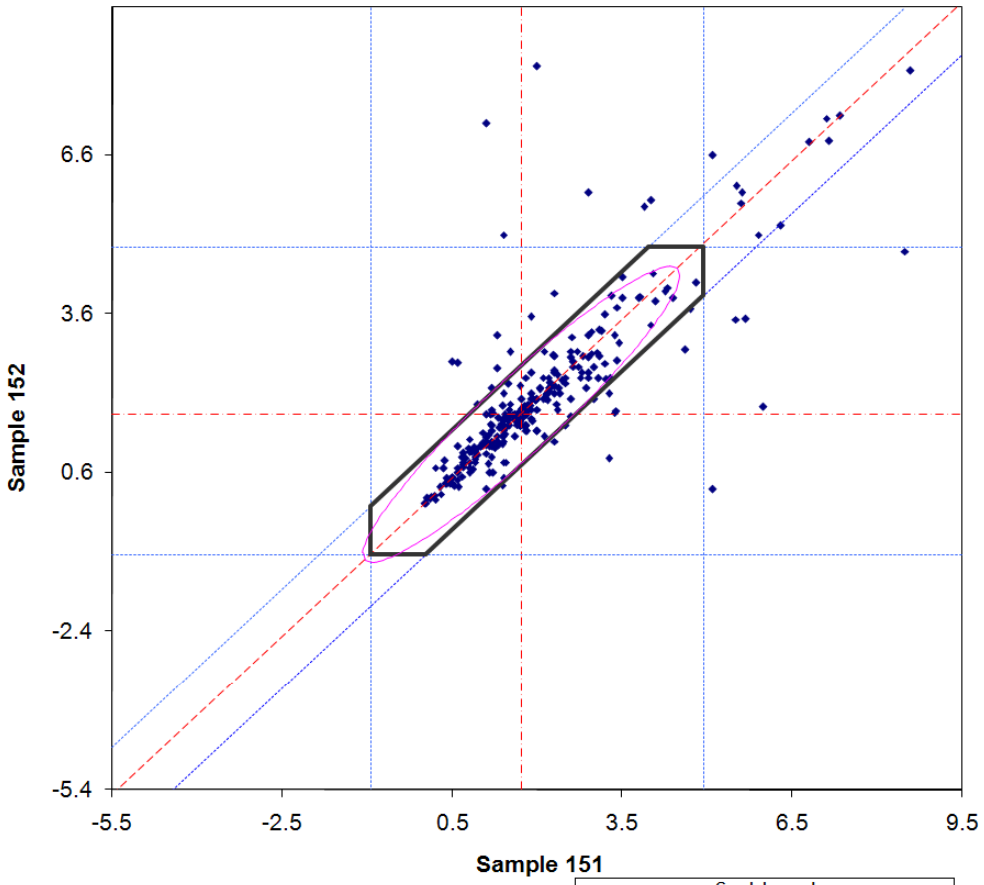
Reproducability (Sample 148)		
1s	d2s	CV%
0.982	2.778	55.32

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

290	Total Laboratories
15	Laboratories Determined to be Invalid
30	Laboratories Determined to be Outliers
245	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
1.718	1.706

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.222	0.628	12.93	13.02

Reproducability (Sample 151)		
1s	d2s	CV%
0.928	2.624	54.00

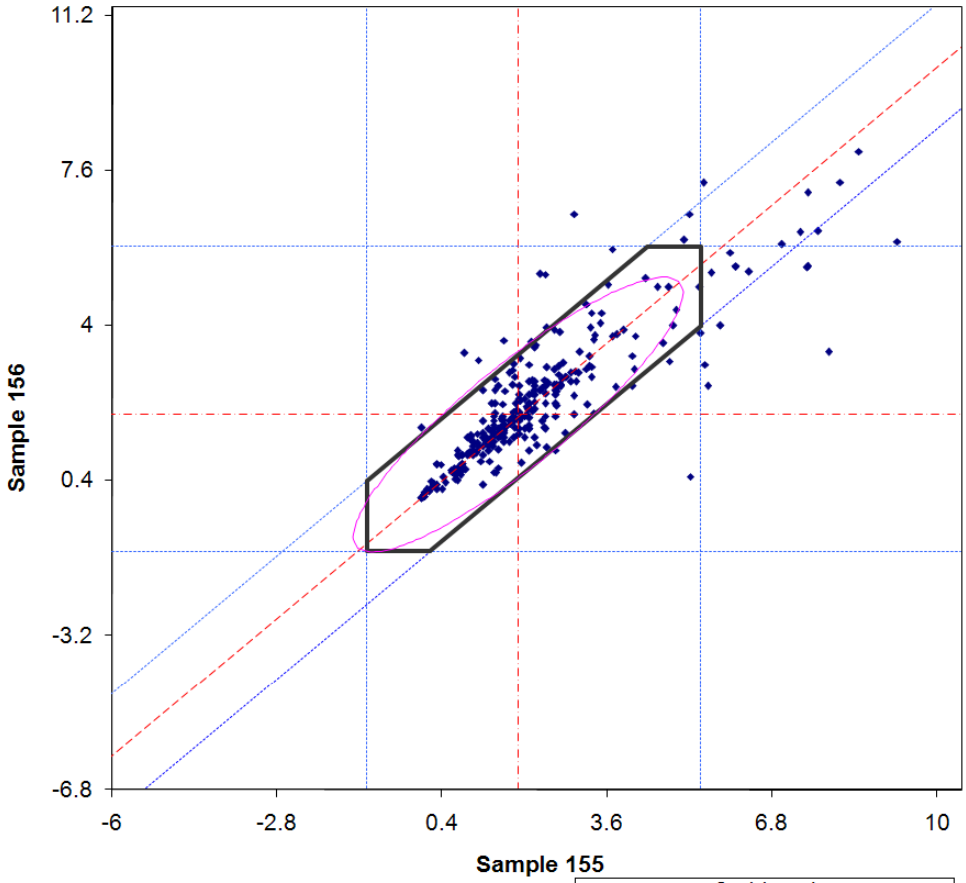
Reproducability (Sample 152)		
1s	d2s	CV%
0.911	2.577	53.43

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

301	Total Laboratories
8	Laboratories Determined to be Invalid
30	Laboratories Determined to be Outliers
263	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
1.877	1.937

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.358	1.012	19.07	18.48

Reproducability (Sample 155)		
1s	d2s	CV%
1.008	2.852	53.71

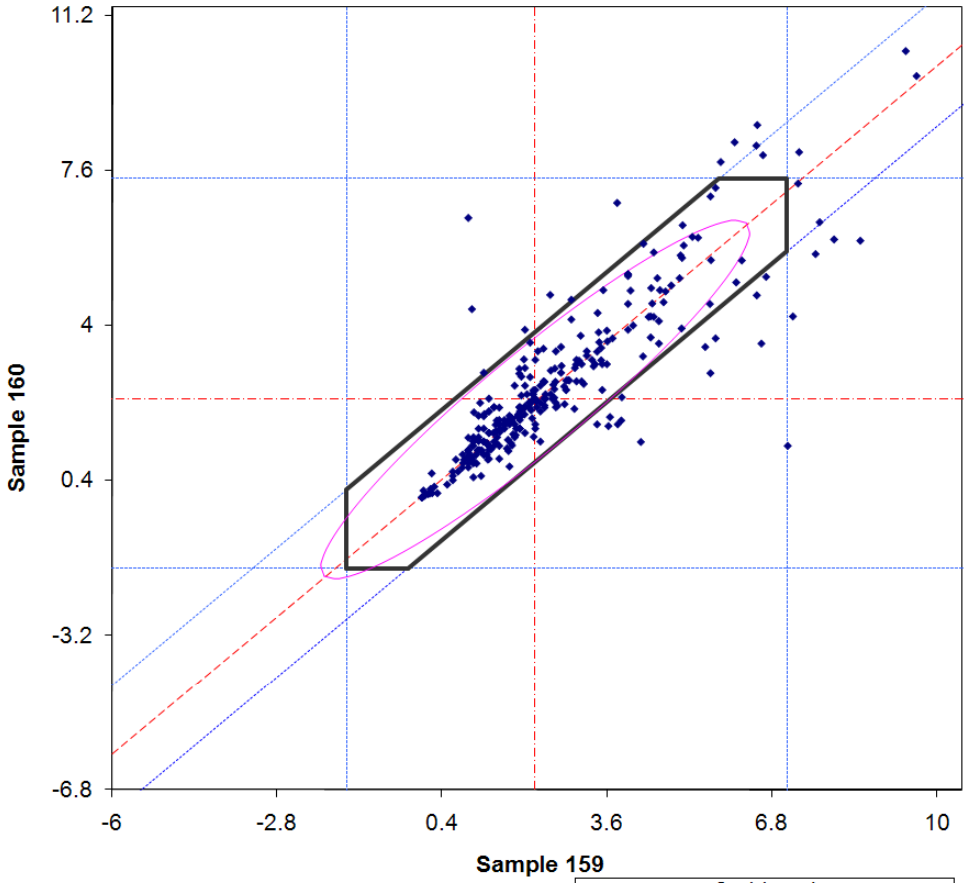
Reproducability (Sample 156)		
1s	d2s	CV%
1.062	3.003	54.80

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

320	Total Laboratories
17	Laboratories Determined to be Invalid
31	Laboratories Determined to be Outliers
272	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
2.205	2.295

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.346	0.979	15.70	15.08

Reproducability (Sample 159)		
1s	d2s	CV%
1.310	3.705	59.40

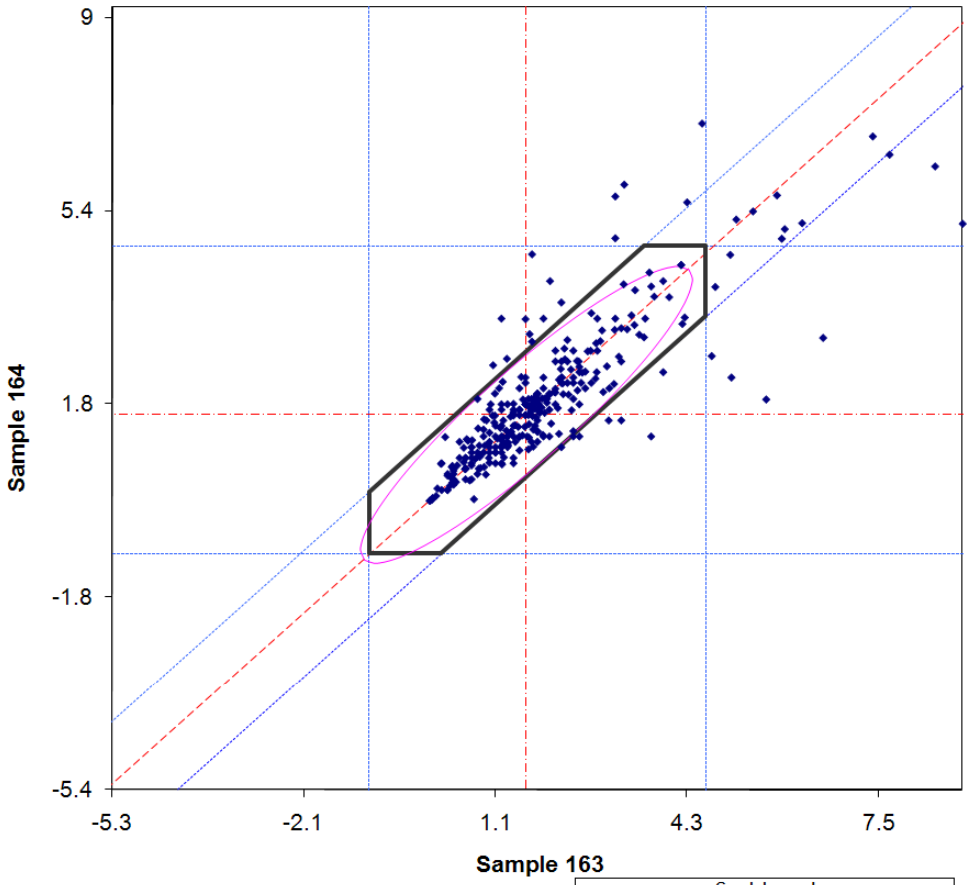
Reproducability (Sample 160)		
1s	d2s	CV%
1.421	4.019	61.91

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Sodium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

330	Total Laboratories
23	Laboratories Determined to be Invalid
28	Laboratories Determined to be Outliers
279	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
1.612	1.611

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.268	0.757	16.62	16.62

Reproducability (Sample 163)		
1s	d2s	CV%
0.906	2.561	56.18

Reproducability (Sample 164)		
1s	d2s	CV%
0.900	2.546	55.88

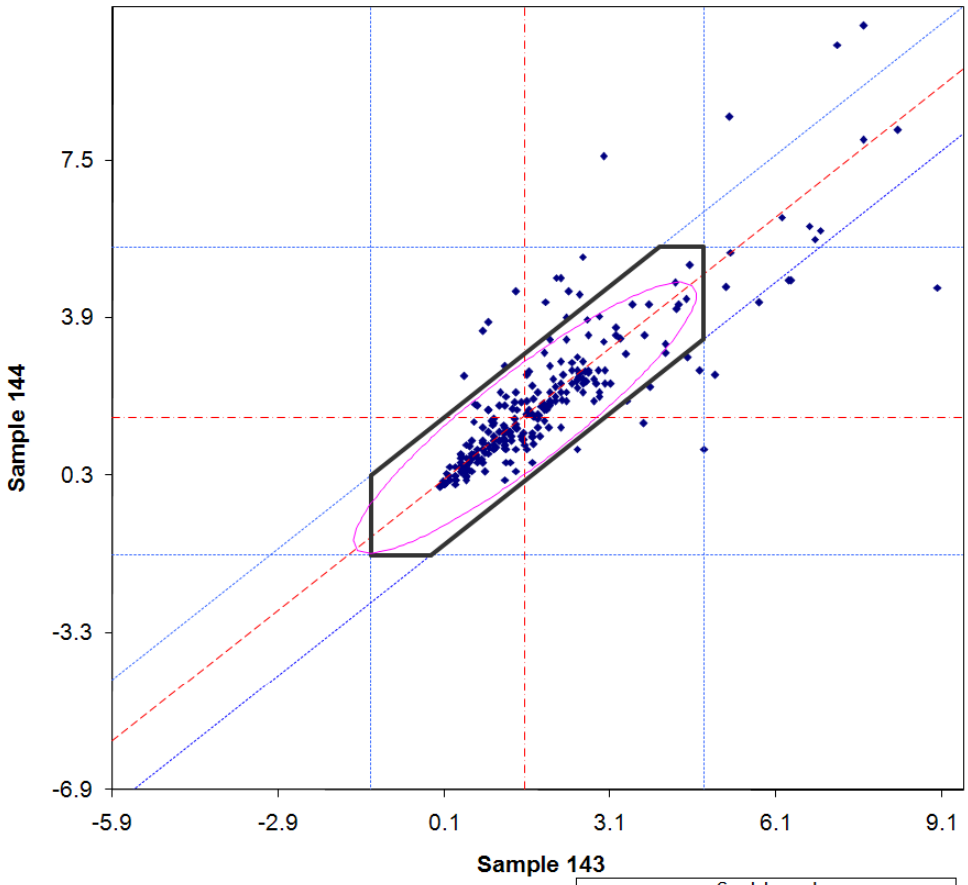
APPENDIX I: SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, MATERIAL FINER THAN 300-μM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

266	Total Laboratories
14	Laboratories Determined to be Invalid
30	Laboratories Determined to be Outliers
222	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
1.558	1.620

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.311	0.880	19.98	19.22

Reproducability (Sample 143)		
1s	d2s	CV%
0.986	2.790	63.31

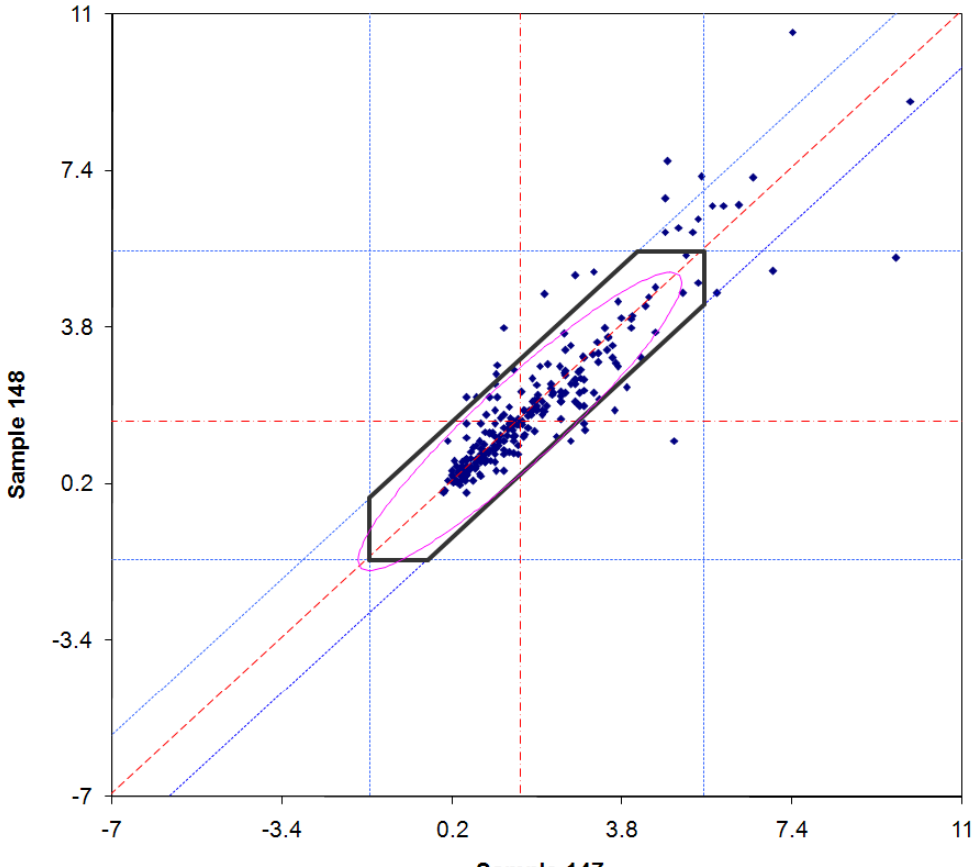
Reproducability (Sample 144)		
1s	d2s	CV%
1.029	2.909	63.52

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

262	Total Laboratories
9	Laboratories Determined to be Invalid
25	Laboratories Determined to be Outliers
228	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
1.632	1.644

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.294	0.833	18.04	17.91

Reproducability (Sample 147)		
1s	d2s	CV%
1.147	3.244	70.28

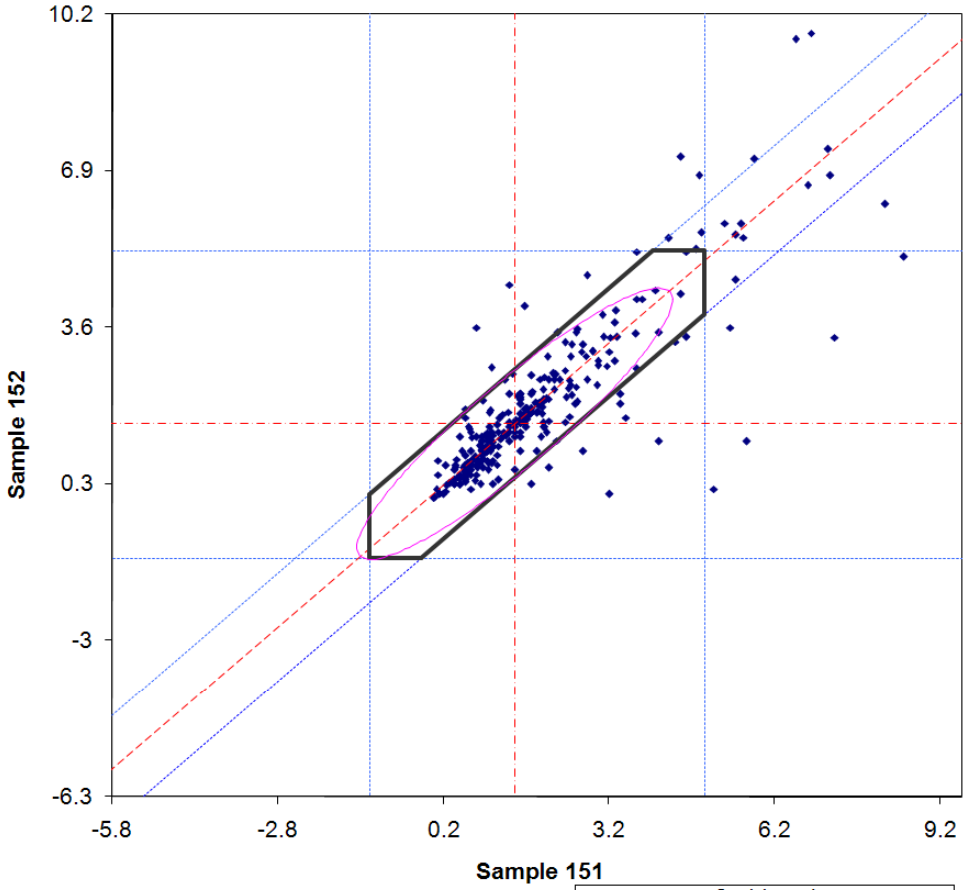
Reproducability (Sample 148)		
1s	d2s	CV%
1.100	3.110	66.88

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

291	Total Laboratories
15	Laboratories Determined to be Invalid
29	Laboratories Determined to be Outliers
247	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
1.490	1.571

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.274	0.774	18.38	17.43

Reproducability (Sample 151)		
1s	d2s	CV%
0.905	2.559	60.74

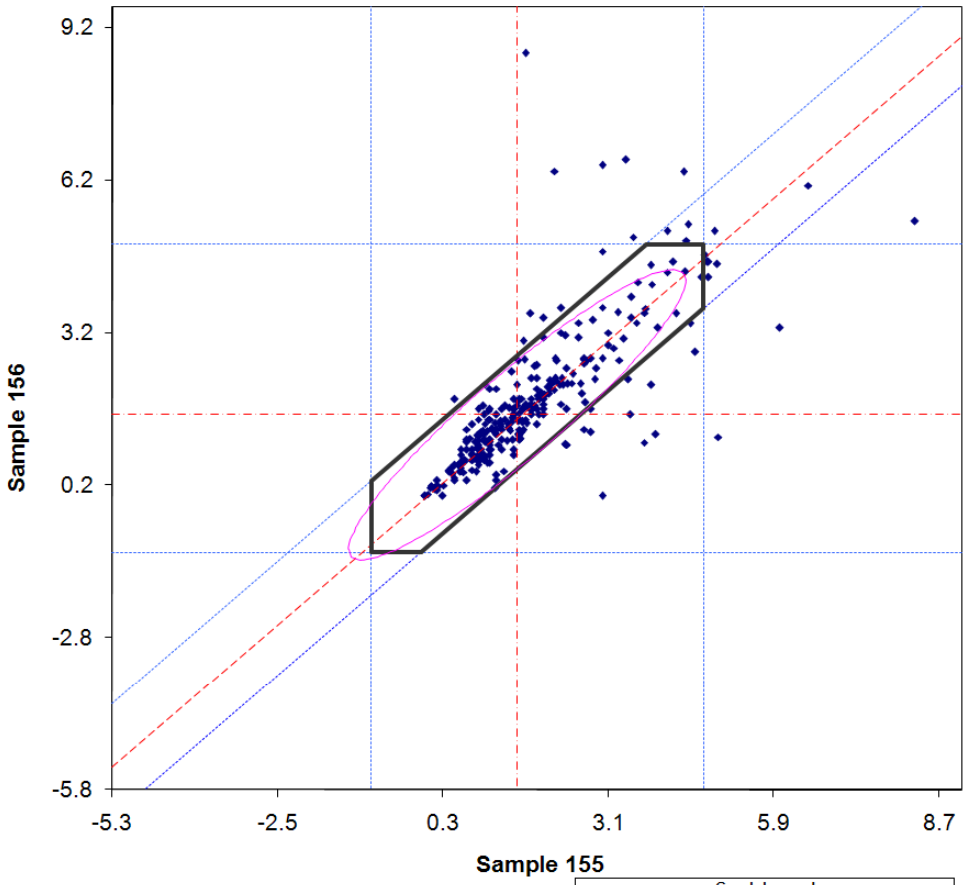
Reproducability (Sample 152)		
1s	d2s	CV%
0.962	2.722	61.25

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

300	Total Laboratories
16	Laboratories Determined to be Invalid
30	Laboratories Determined to be Outliers
254	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
1.558	1.587

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.257	0.727	16.49	16.19

Reproducability (Sample 155)		
1s	d2s	CV%
0.912	2.579	58.50

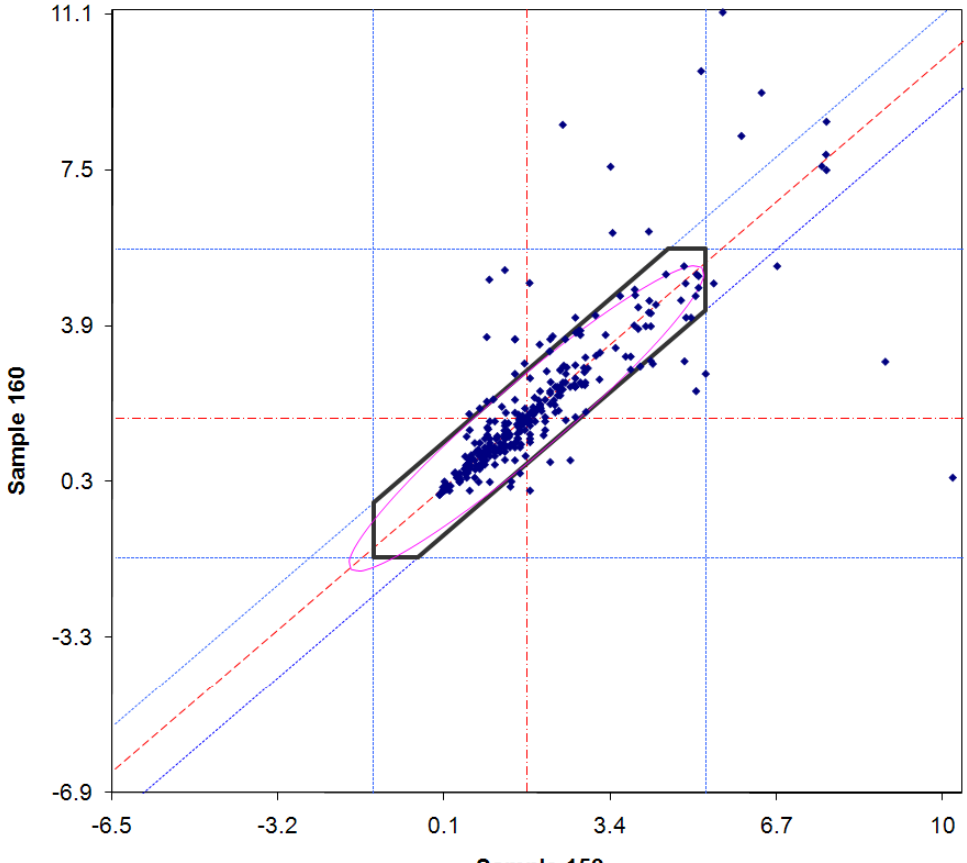
Reproducability (Sample 156)		
1s	d2s	CV%
0.957	2.707	60.31

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 159 and 160
Final Report Issued March 2007

Participation:

320	Total Laboratories
19	Laboratories Determined to be Invalid
31	Laboratories Determined to be Outliers
270	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
1.733	1.767

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.248	0.702	14.32	14.05

Reproducability (Sample 159)		
1s	d2s	CV%
1.148	3.247	66.24

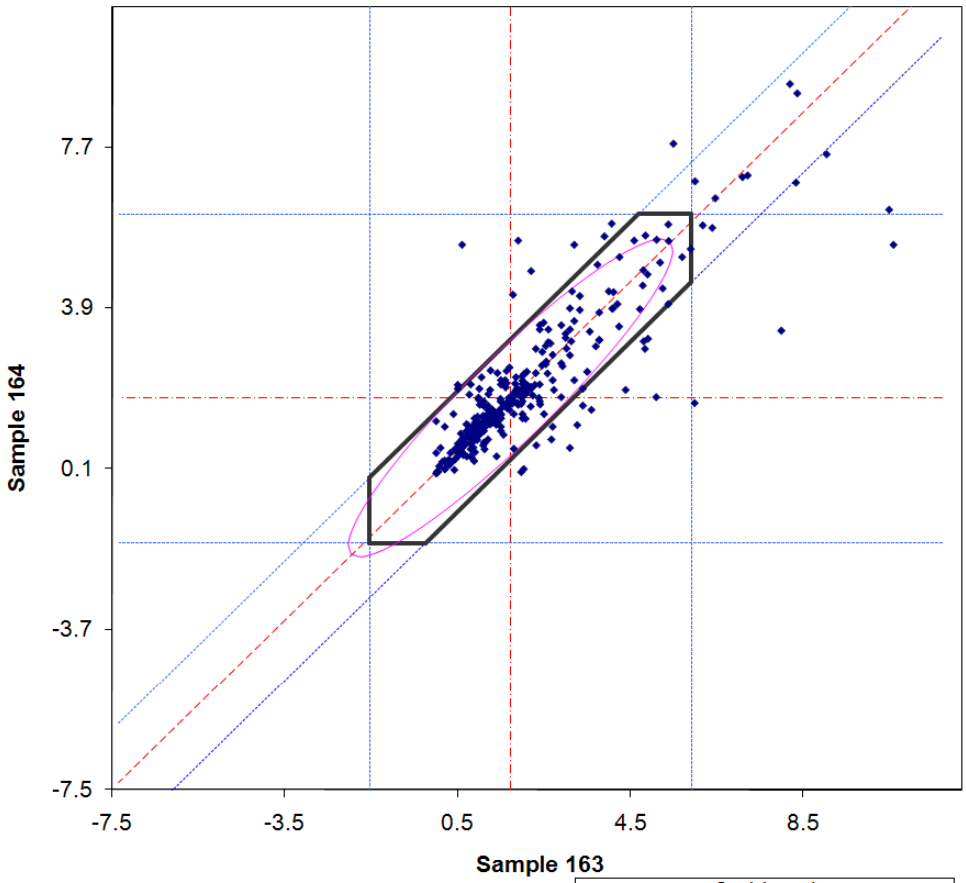
Reproducability (Sample 160)		
1s	d2s	CV%
1.174	3.322	66.47

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Sodium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

329	Total Laboratories
21	Laboratories Determined to be Invalid
31	Laboratories Determined to be Outliers
277	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
1.730	1.776

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.325	0.919	18.78	18.29

Reproducability (Sample 163)		
1s	d2s	CV%
1.231	3.483	71.18

Reproducability (Sample 164)		
1s	d2s	CV%
1.231	3.481	69.29

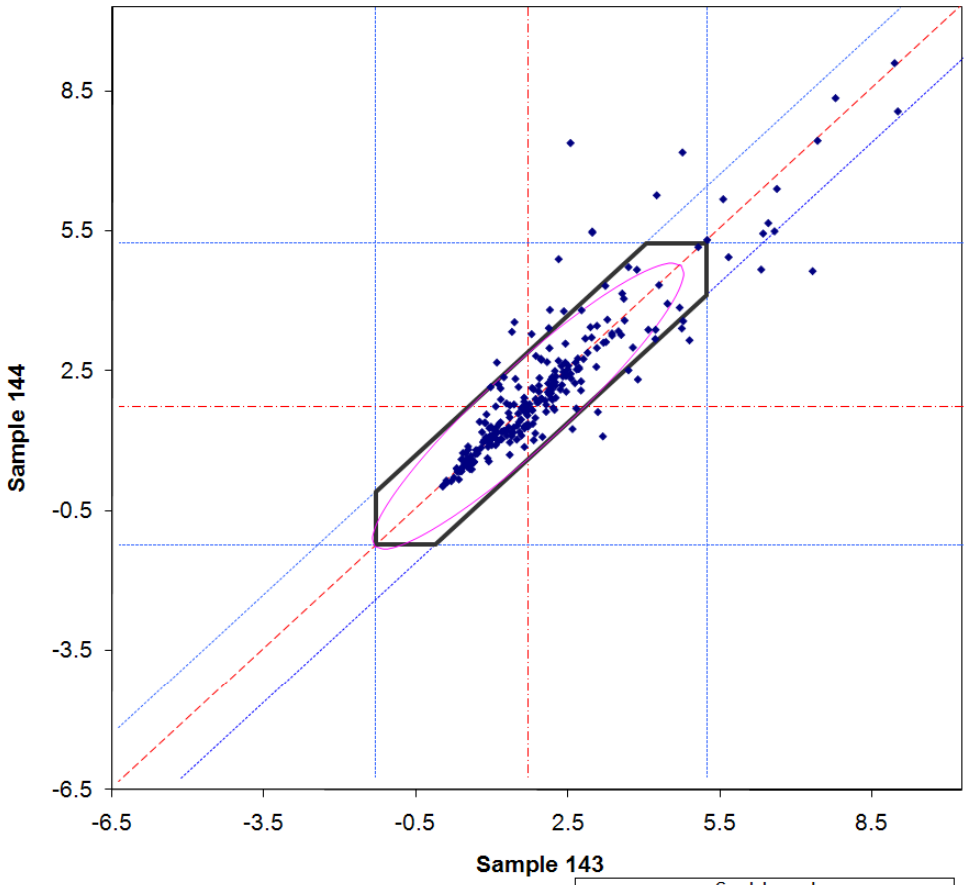
APPENDIX J: WEIGHTED AVERAGE SOUNDNESS MEASUREMENTS USING SODIUM SULFATE, FINE AGGREGATE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

266	Total Laboratories
15	Laboratories Determined to be Invalid
26	Laboratories Determined to be Outliers
225	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
1.716	1.746

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.273	0.772	15.9	15.6

Reproducability (Sample 143)		
1s	d2s	CV%
1.005	2.843	58.6

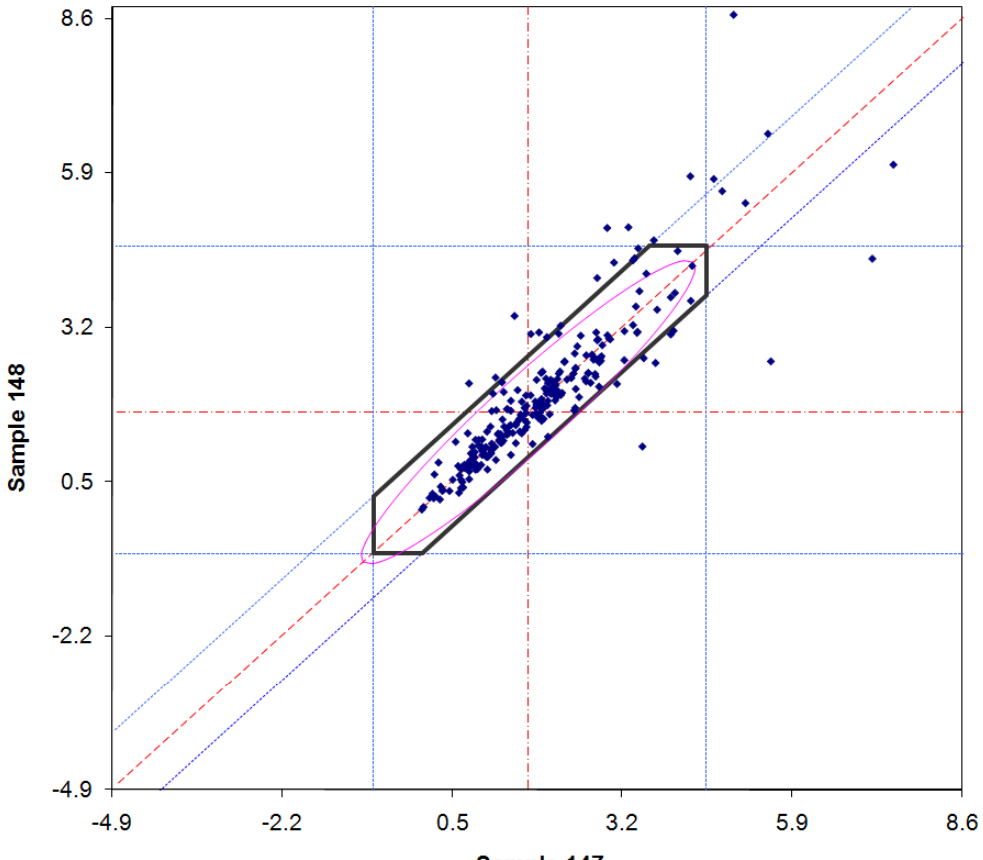
Reproducability (Sample 144)		
1s	d2s	CV%
1.009	2.855	57.8

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

259	Total Laboratories
12	Laboratories Determined to be Invalid
24	Laboratories Determined to be Outliers
223	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
1.703	1.720

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.197	0.557	11.6	11.4

Reproducability (Sample 147)		
1s	d2s	CV%
0.885	2.502	51.9

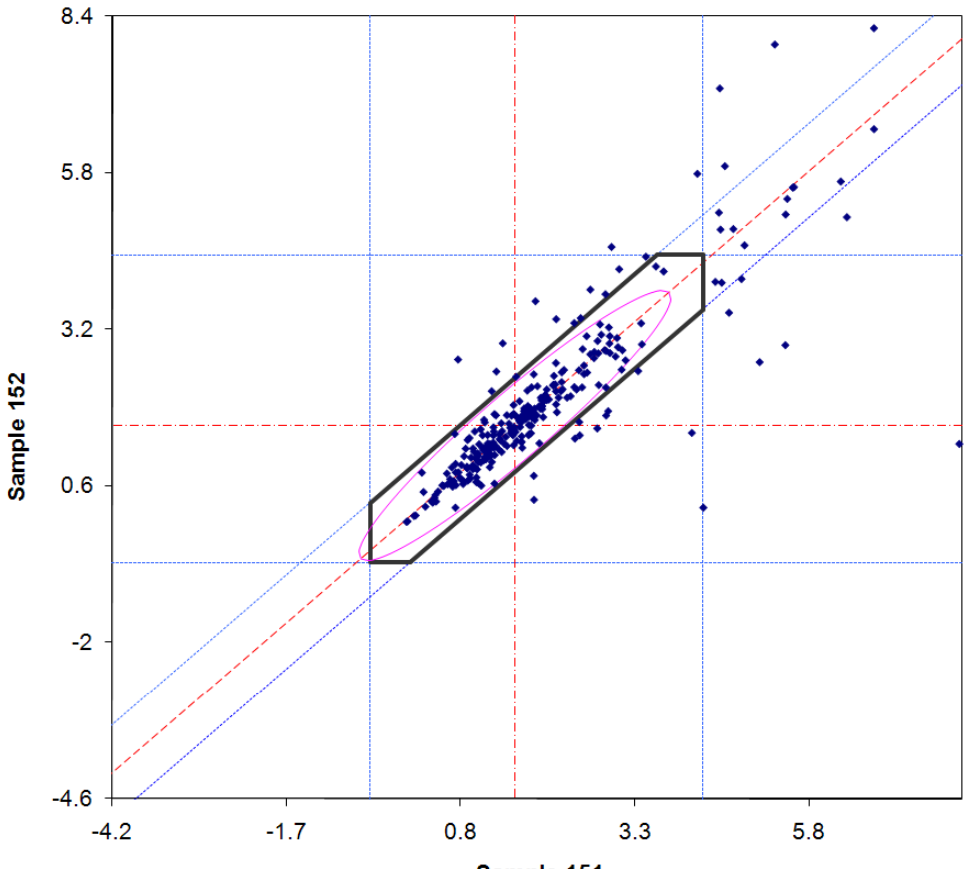
Reproducability (Sample 148)		
1s	d2s	CV%
0.864	2.444	50.2

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

289	Total Laboratories
14	Laboratories Determined to be Invalid
37	Laboratories Determined to be Outliers
238	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
1.578	1.606

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.167	0.472	10.6	10.4

Reproducability (Sample 151)		
1s	d2s	CV%
0.729	2.061	46.2

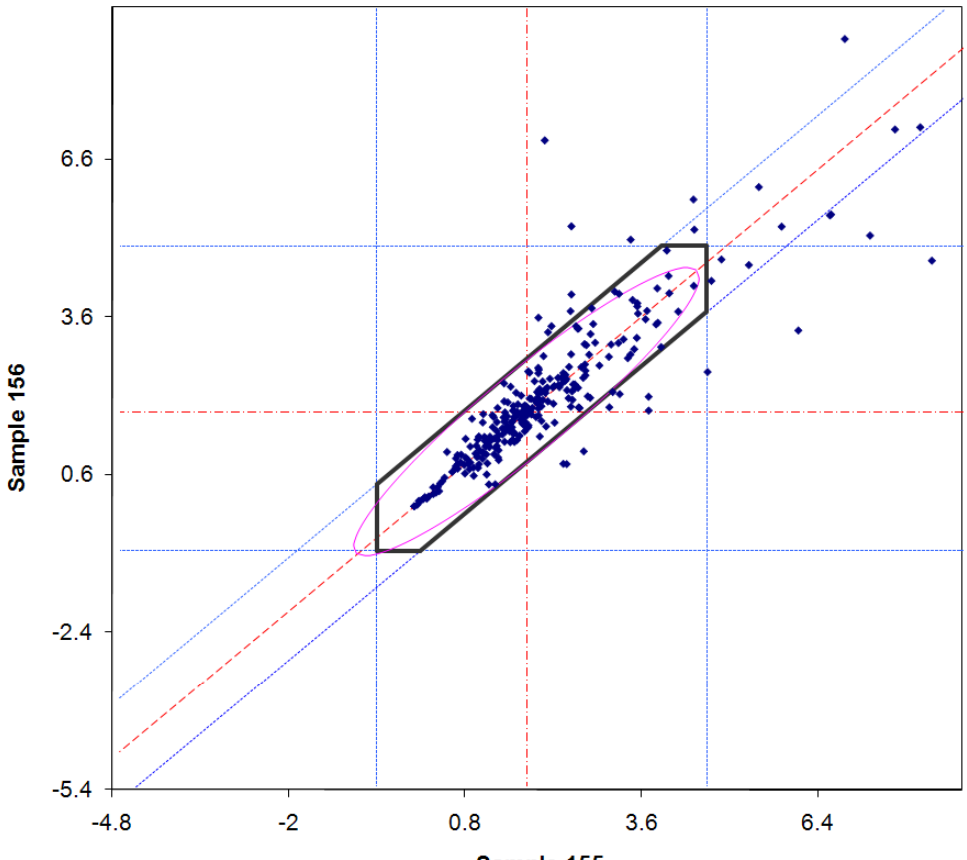
Reproducability (Sample 152)		
1s	d2s	CV%
0.745	2.107	46.4

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

298	Total Laboratories
13	Laboratories Determined to be Invalid
22	Laboratories Determined to be Outliers
263	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
1.777	1.804

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.234	0.661	13.1	13.0

Reproducability (Sample 155)		
1s	d2s	CV%
0.878	2.484	49.4

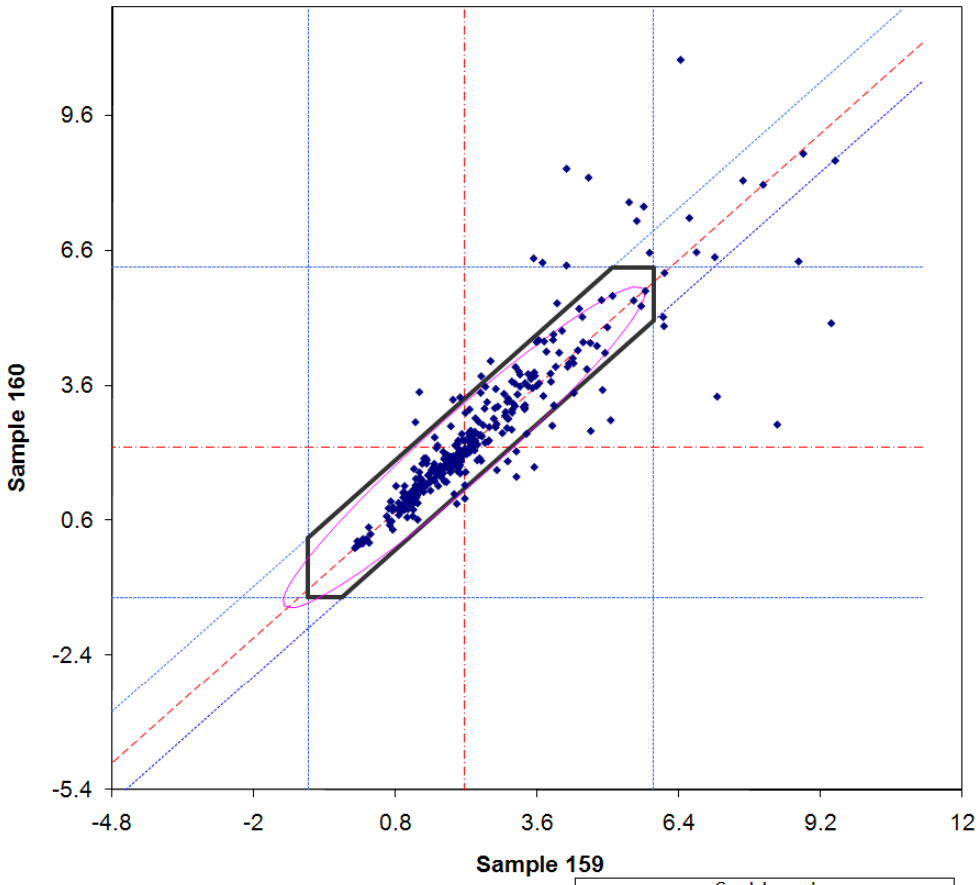
Reproducability (Sample 156)		
1s	d2s	CV%
0.919	2.599	50.9

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 159 and 160
Final Report Issued March 2009

Participation:

320	Total Laboratories
18	Laboratories Determined to be Invalid
30	Laboratories Determined to be Outliers
272	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
2.147	2.226

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.230	0.652	10.7	10.4

Reproducability (Sample 159)		
1s	d2s	CV%
1.143	3.232	53.2

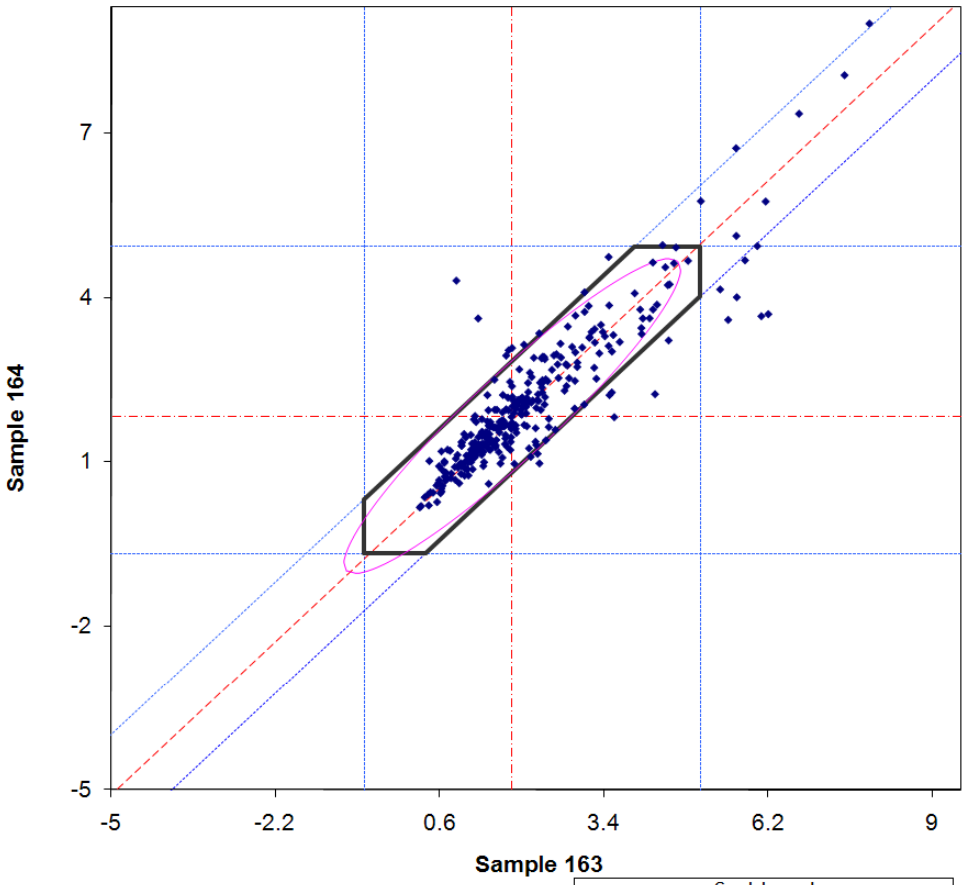
Reproducability (Sample 160)		
1s	d2s	CV%
1.213	3.430	54.5

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Weighted Average Soundness Loss Using Sodium Sulfate, Fine Aggregate



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

329	Total Laboratories
20	Laboratories Determined to be Invalid
27	Laboratories Determined to be Outliers
282	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
1.837	1.834

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.243	0.687	13.2	13.2

Reproducability (Sample 163)		
1s	d2s	CV%
0.945	2.673	51.4

Reproducability (Sample 164)		
1s	d2s	CV%
0.938	2.652	51.1

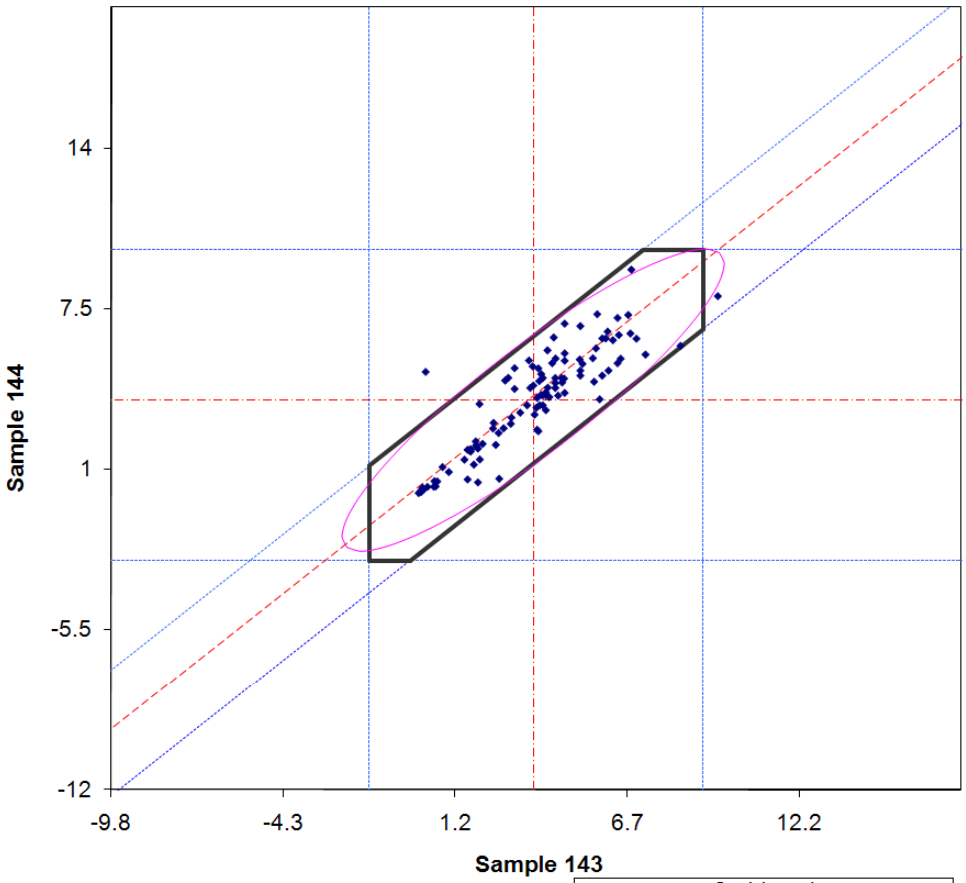
APPENDIX K: SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, MATERIAL FINER THAN 1.18-MM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18-mm Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

107	Total Laboratories
1	Laboratories Determined to be Invalid
2	Laboratories Determined to be Outliers
104	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
3.70	3.81

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.634	1.795	17.1	16.7

Reproducability (Sample 143)		
1s	d2s	CV%
1.911	5.404	51.6

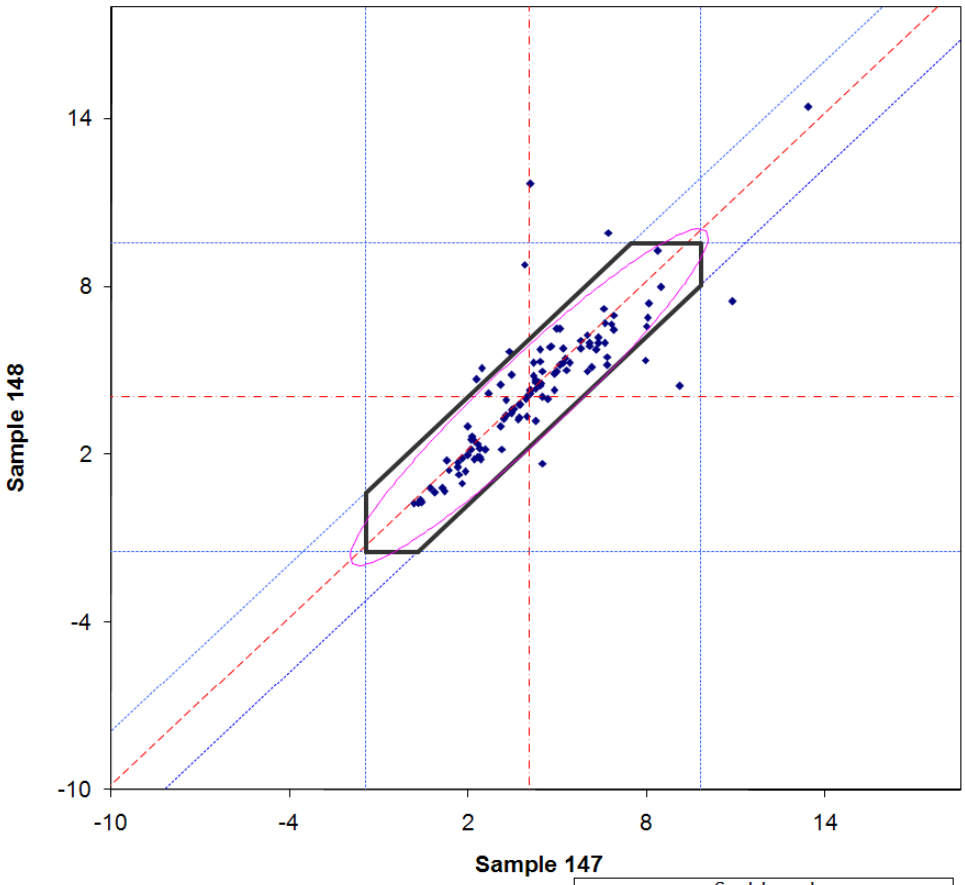
Reproducability (Sample 144)		
1s	d2s	CV%
2.054	5.809	54.0

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

113	Total Laboratories
5	Laboratories Determined to be Invalid
7	Laboratories Determined to be Outliers
101	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
4.054	4.066

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.443	1.252	10.92	10.89

Reproducability (Sample 147)		
1s	d2s	CV%
1.982	5.606	48.90

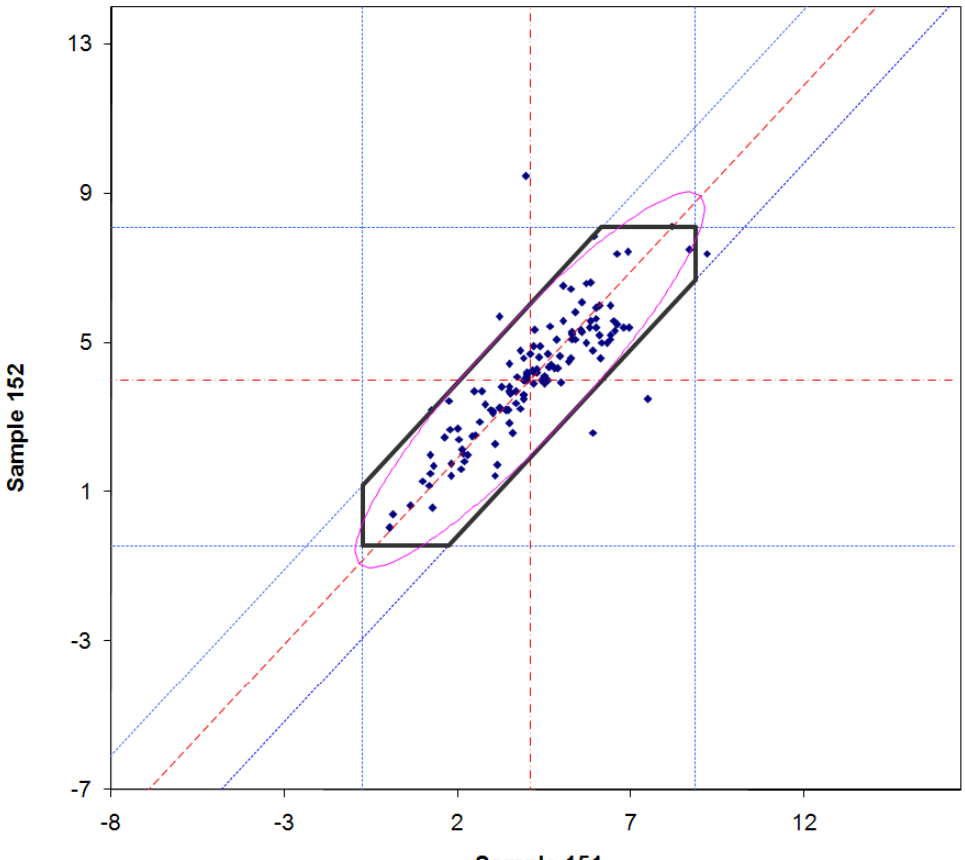
Reproducability (Sample 148)		
1s	d2s	CV%
1.983	5.610	48.78

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

133	Total Laboratories
2	Laboratories Determined to be Invalid
5	Laboratories Determined to be Outliers
126	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
4.087	4.009

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.488	1.381	11.95	12.18

Reproducability (Sample 151)		
1s	d2s	CV%
1.688	4.775	41.31

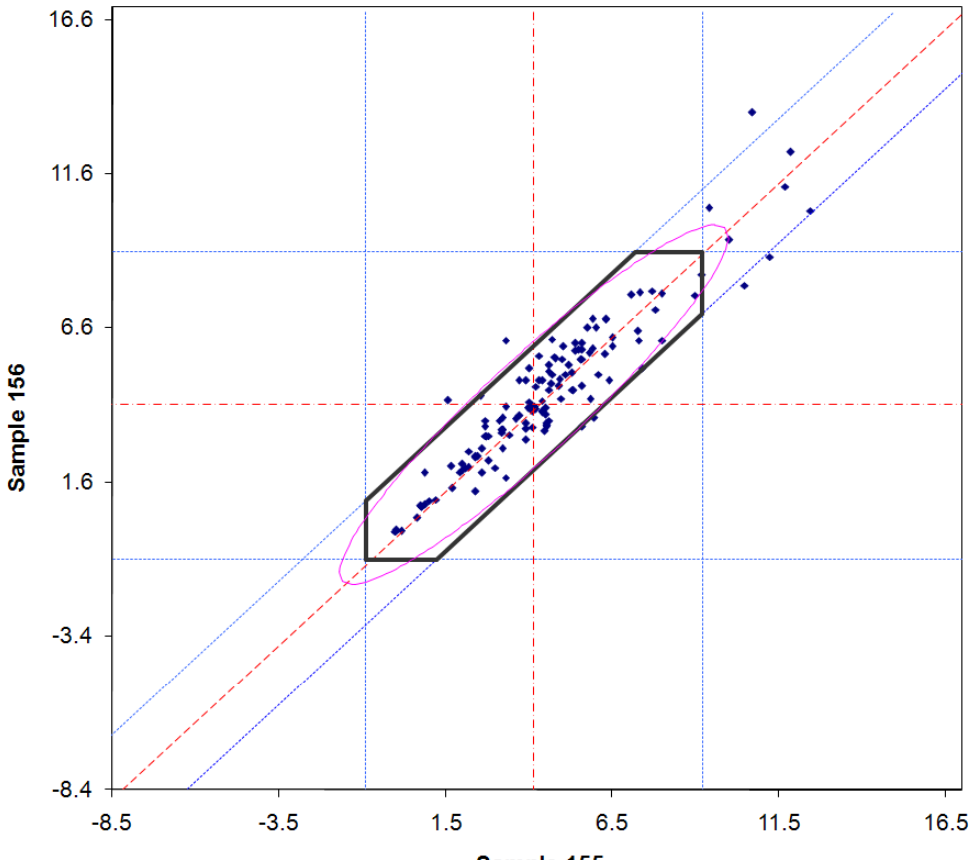
Reproducability (Sample 152)		
1s	d2s	CV%
1.595	4.512	39.80

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

143	Total Laboratories
11	Laboratories Determined to be Invalid
5	Laboratories Determined to be Outliers
127	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
4.145	4.108

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.495	1.399	11.93	12.04

Reproducability (Sample 155)		
1s	d2s	CV%
1.930	5.459	46.56

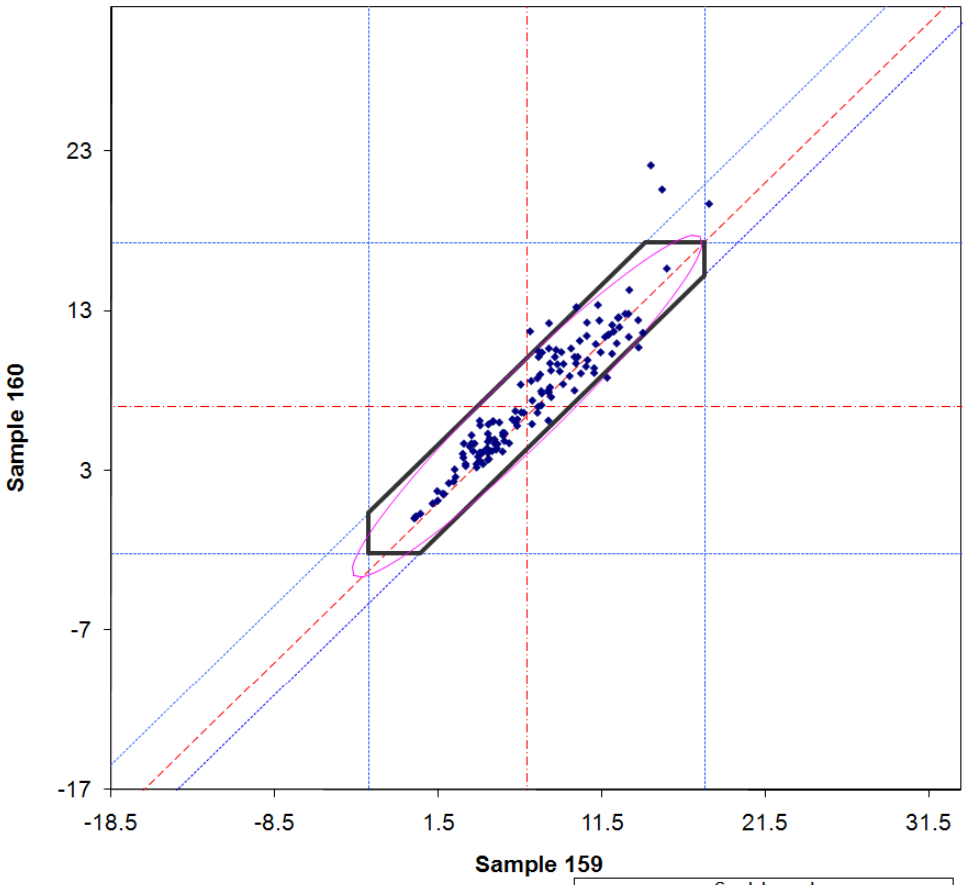
Reproducability (Sample 156)		
1s	d2s	CV%
1.894	5.358	46.11

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

140	Total Laboratories
3	Laboratories Determined to be Invalid
7	Laboratories Determined to be Outliers
130	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
6.919	7.030

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.716	2.027	10.36	10.19

Reproducability (Sample 159)		
1s	d2s	CV%
3.550	10.040	51.30

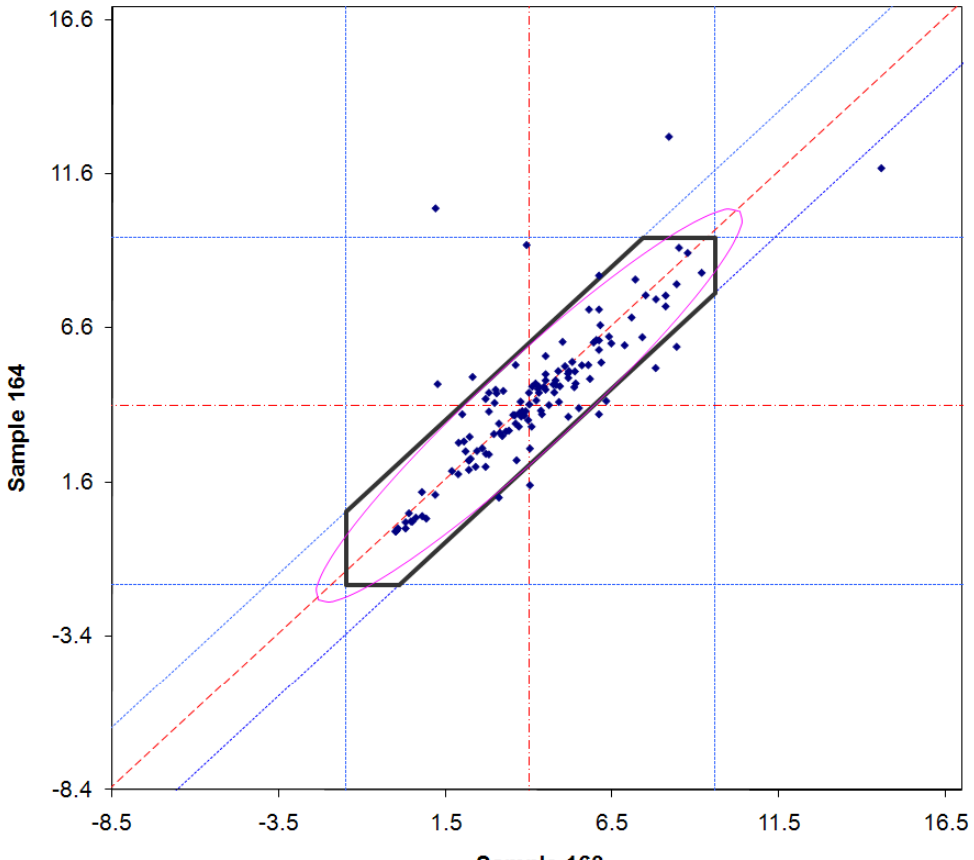
Reproducability (Sample 160)		
1s	d2s	CV%
3.515	9.942	50.00

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Magnesium Sulfate, Material Finer Than the 1.18 mm Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

134	Total Laboratories
5	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
119	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
3.992	4.080

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.465	1.314	11.64	11.39

Reproducability (Sample 163)		
1s	d2s	CV%
2.117	5.987	53.02

Reproducability (Sample 164)		
1s	d2s	CV%
2.092	5.916	51.26

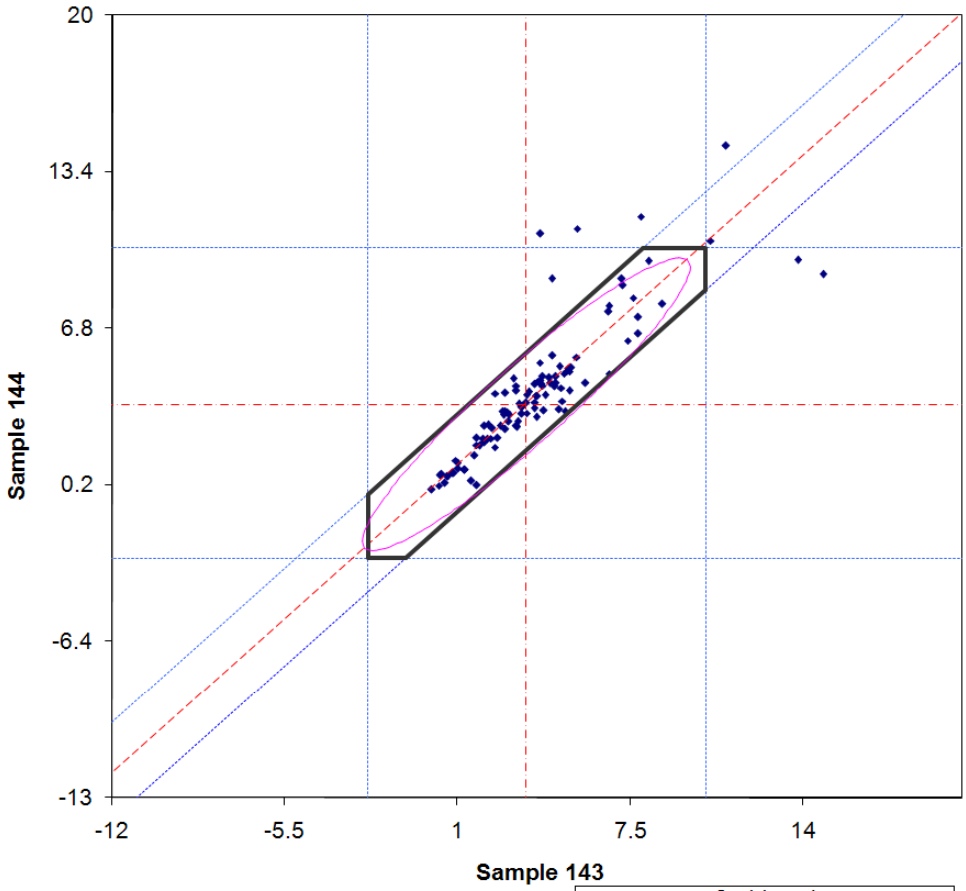
APPENDIX L: SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, MATERIAL FINER THAN 600-μM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

107	Total Laboratories
6	Laboratories Determined to be Invalid
4	Laboratories Determined to be Outliers
97	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
4	4

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.5	1.4	14.2	14.1

Reproducability (Sample 143)		
1s	d2s	CV%
2.0	5.6	55.3

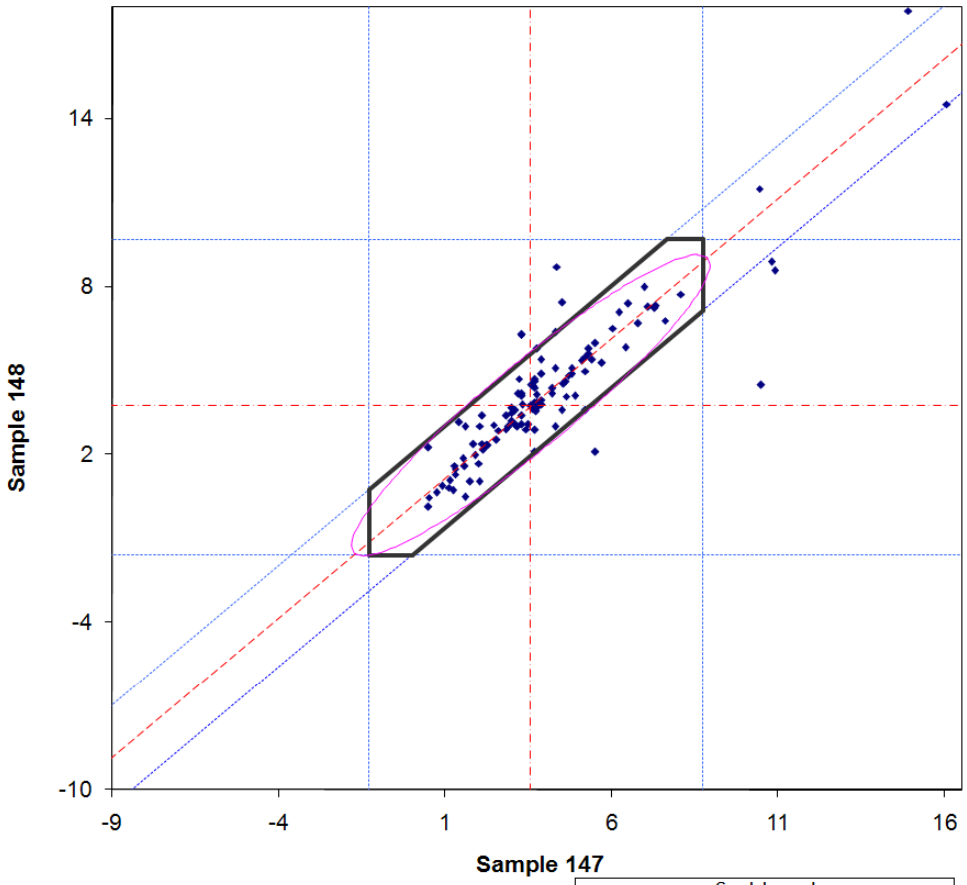
Reproducability (Sample 144)		
1s	d2s	CV%
2.1	5.9	57.2

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

114	Total Laboratories
5	Laboratories Determined to be Invalid
9	Laboratories Determined to be Outliers
100	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
3.569	3.773

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.460	1.301	12.88	12.19

Reproducability (Sample 147)		
1s	d2s	CV%
1.731	4.895	48.49

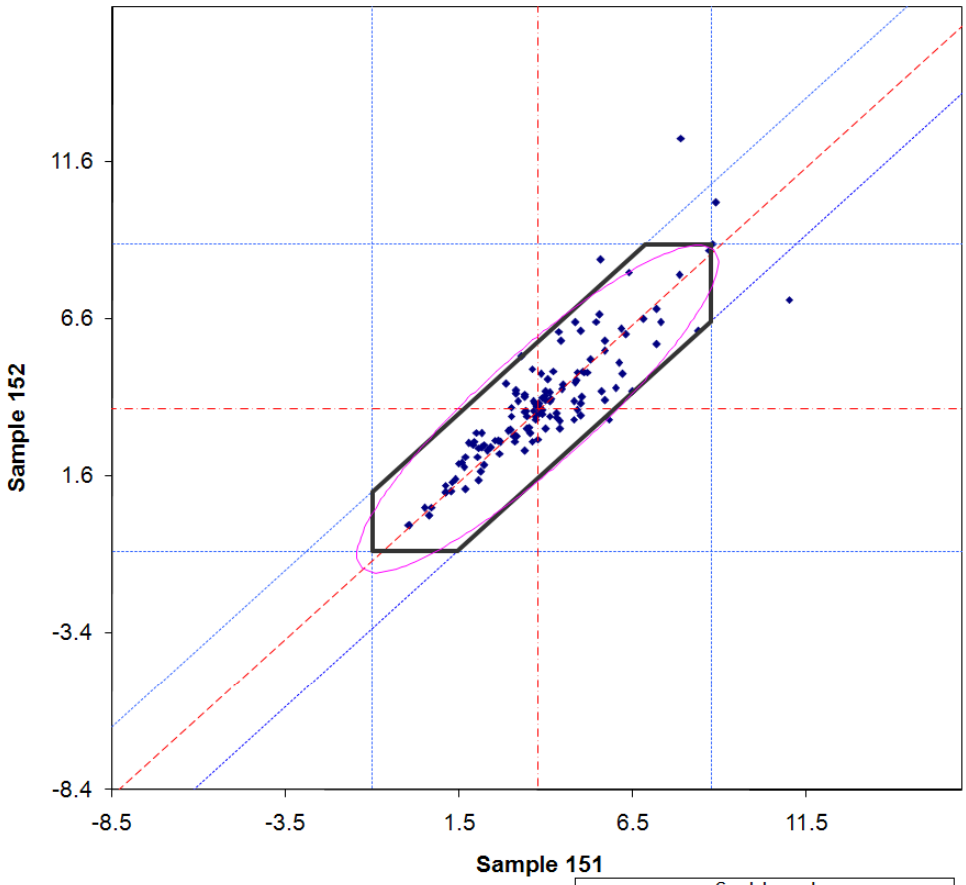
Reproducability (Sample 148)		
1s	d2s	CV%
1.798	5.086	47.67

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

133	Total Laboratories
2	Laboratories Determined to be Invalid
5	Laboratories Determined to be Outliers
126	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
3.754	3.733

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.558	1.579	14.87	14.96

Reproducability (Sample 151)		
1s	d2s	CV%
1.721	4.869	45.85

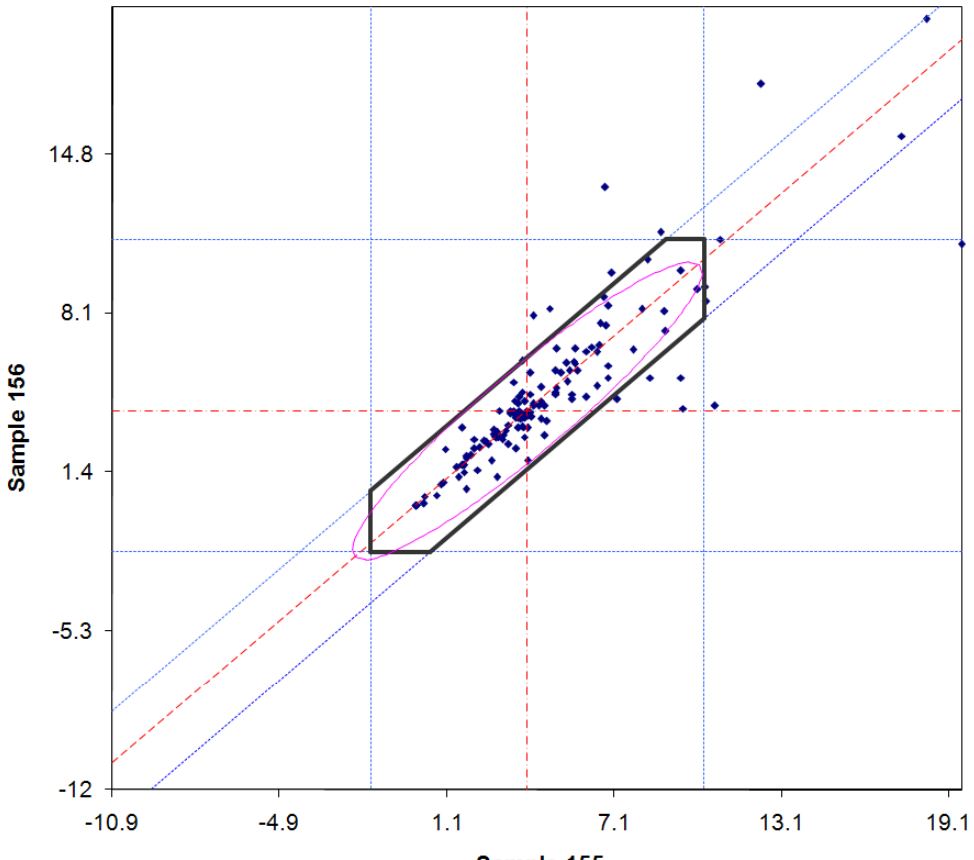
Reproducability (Sample 152)		
1s	d2s	CV%
1.657	4.686	44.38

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

143	Total Laboratories
9	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
122	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
3.989	3.995

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.534	1.511	13.40	13.37

Reproducability (Sample 155)		
1s	d2s	CV%
2.011	5.688	50.42

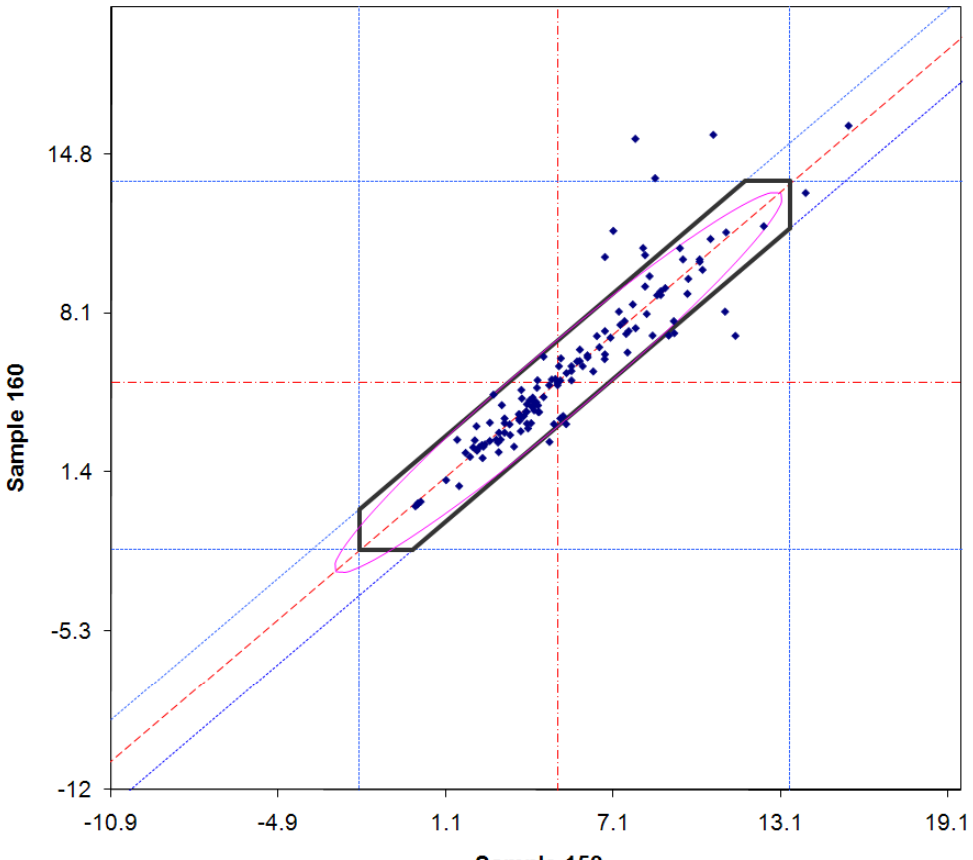
Reproducability (Sample 156)		
1s	d2s	CV%
2.097	5.932	52.49

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

139	Total Laboratories
13	Laboratories Determined to be Invalid
11	Laboratories Determined to be Outliers
115	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
5.135	5.206

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.433	1.225	8.43	8.32

Reproducability (Sample 159)		
1s	d2s	CV%
2.637	7.460	51.36

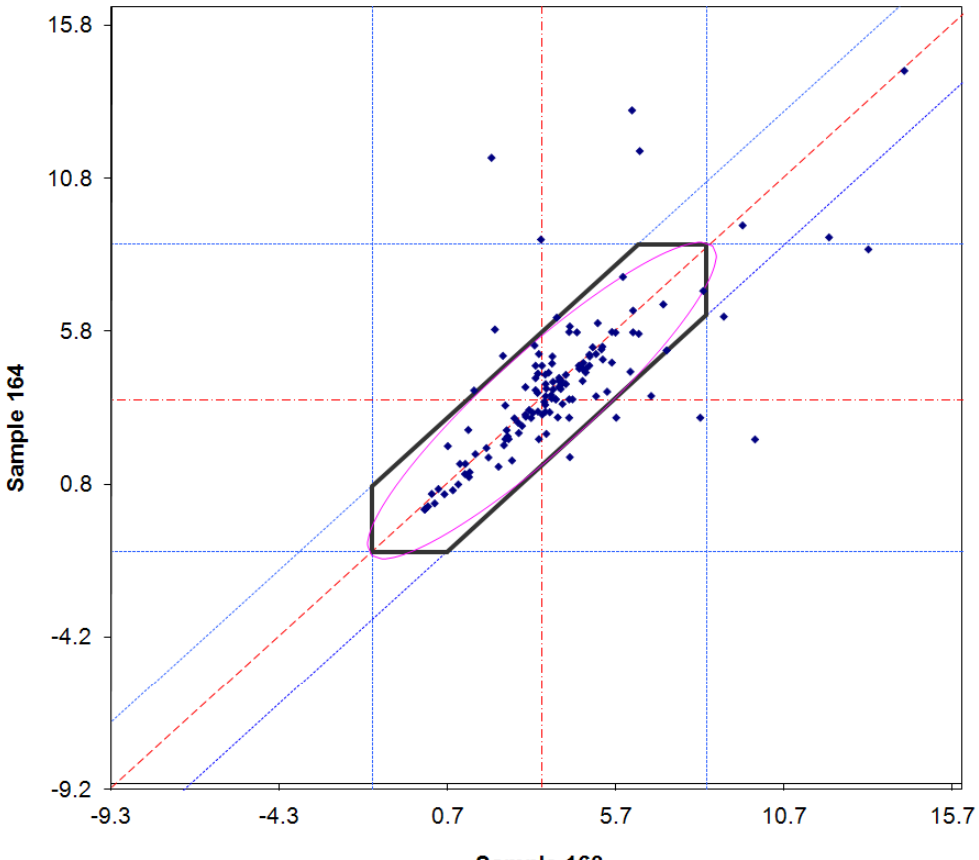
Reproducability (Sample 160)		
1s	d2s	CV%
2.676	7.568	51.40

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Magnesium Sulfate, Material Finer Than the 600 micron Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

134	Total Laboratories
11	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
113	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
3.504	3.555

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.510	1.444	14.57	14.36

Reproducability (Sample 163)		
1s	d2s	CV%
1.690	4.779	48.22

Reproducability (Sample 164)		
1s	d2s	CV%
1.686	4.769	47.43

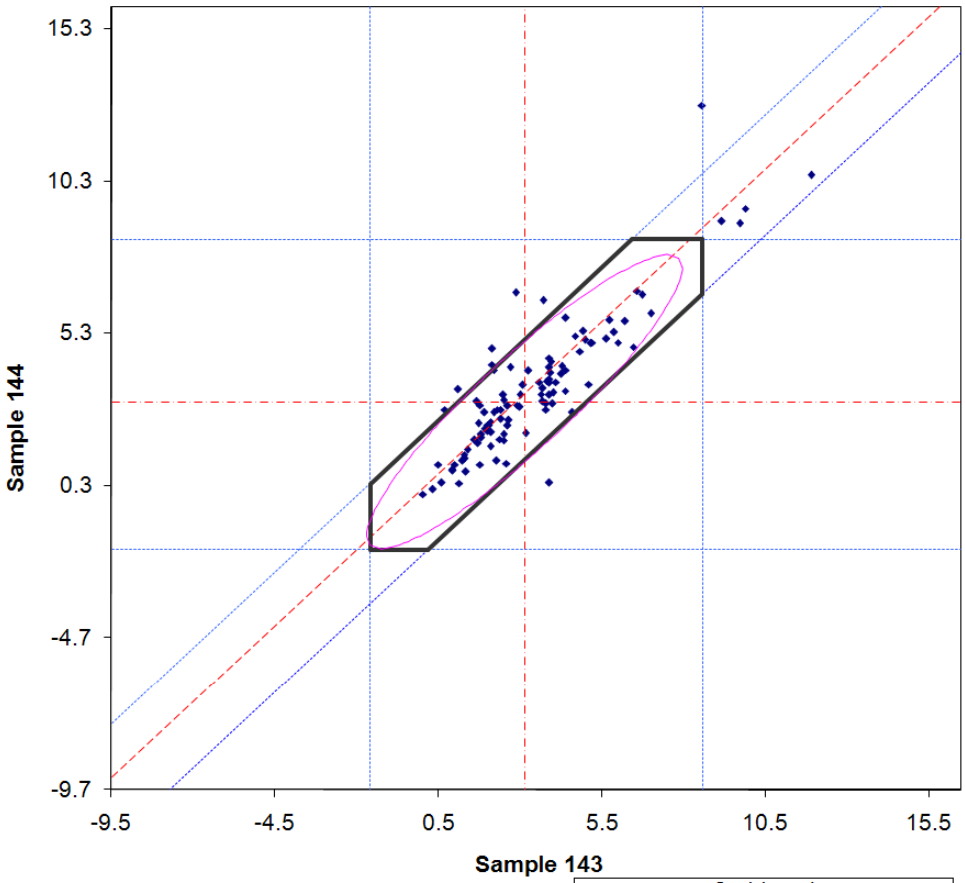
APPENDIX M: SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, MATERIAL FINER THAN 300-μM SIEVE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

107	Total Laboratories
4	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
91	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
3	3

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.5	1.4	15.3	15.7

Reproducability (Sample 143)		
1s	d2s	CV%
1.6	4.5	51.2

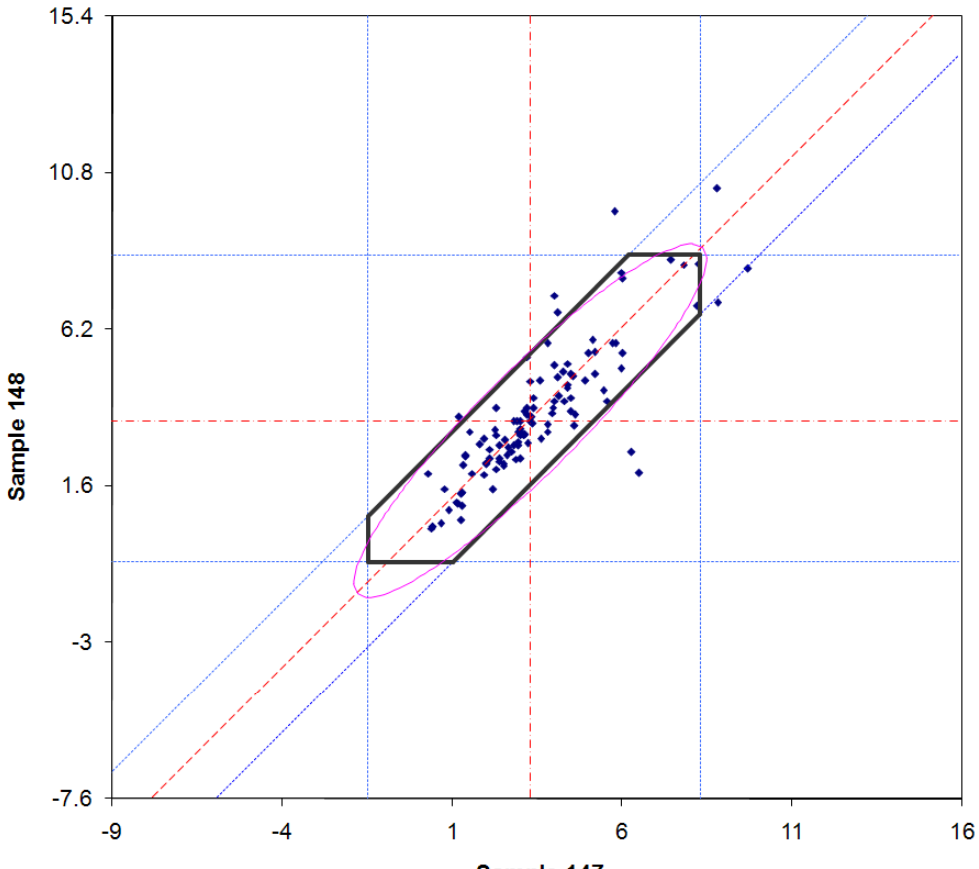
Reproducability (Sample 144)		
1s	d2s	CV%
1.5	4.4	50.4

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

114	Total Laboratories
4	Laboratories Determined to be Invalid
6	Laboratories Determined to be Outliers
104	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
3.290	3.523

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.493	1.395	14.99	14.00

Reproducability (Sample 147)		
1s	d2s	CV%
1.684	4.763	51.18

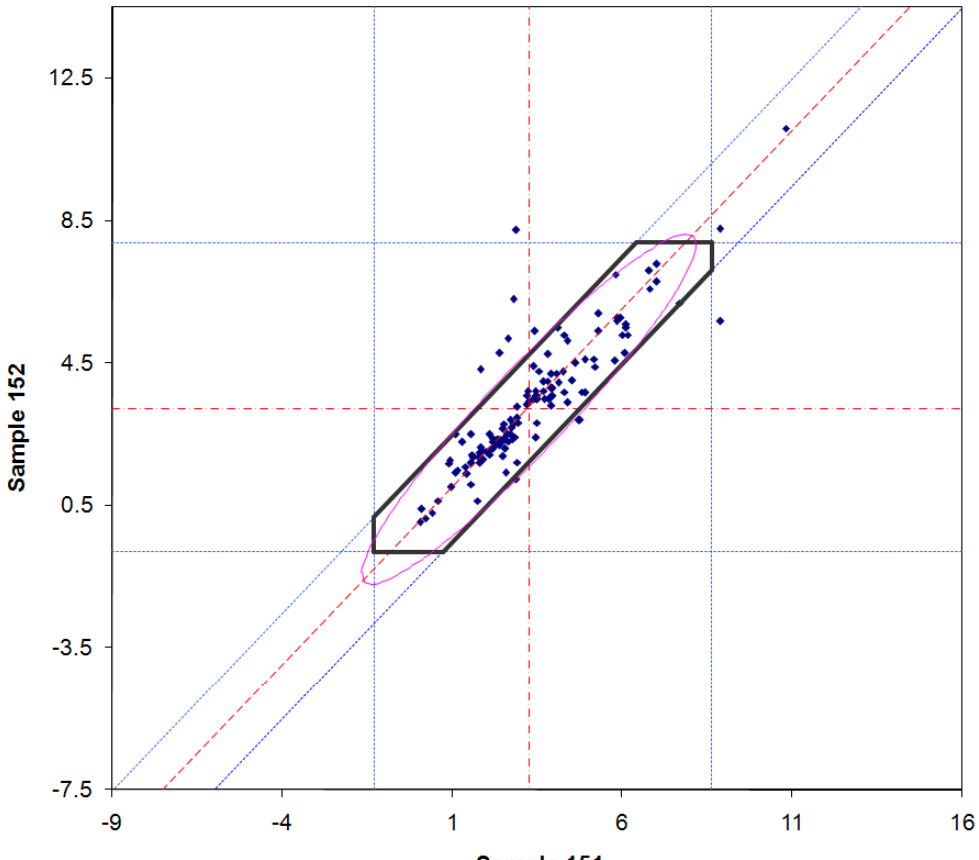
Reproducability (Sample 148)		
1s	d2s	CV%
1.706	4.824	48.41

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

132	Total Laboratories
4	Laboratories Determined to be Invalid
9	Laboratories Determined to be Outliers
119	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
3.251	3.212

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.388	1.097	11.93	12.08

Reproducability (Sample 151)		
1s	d2s	CV%
1.657	4.686	50.96

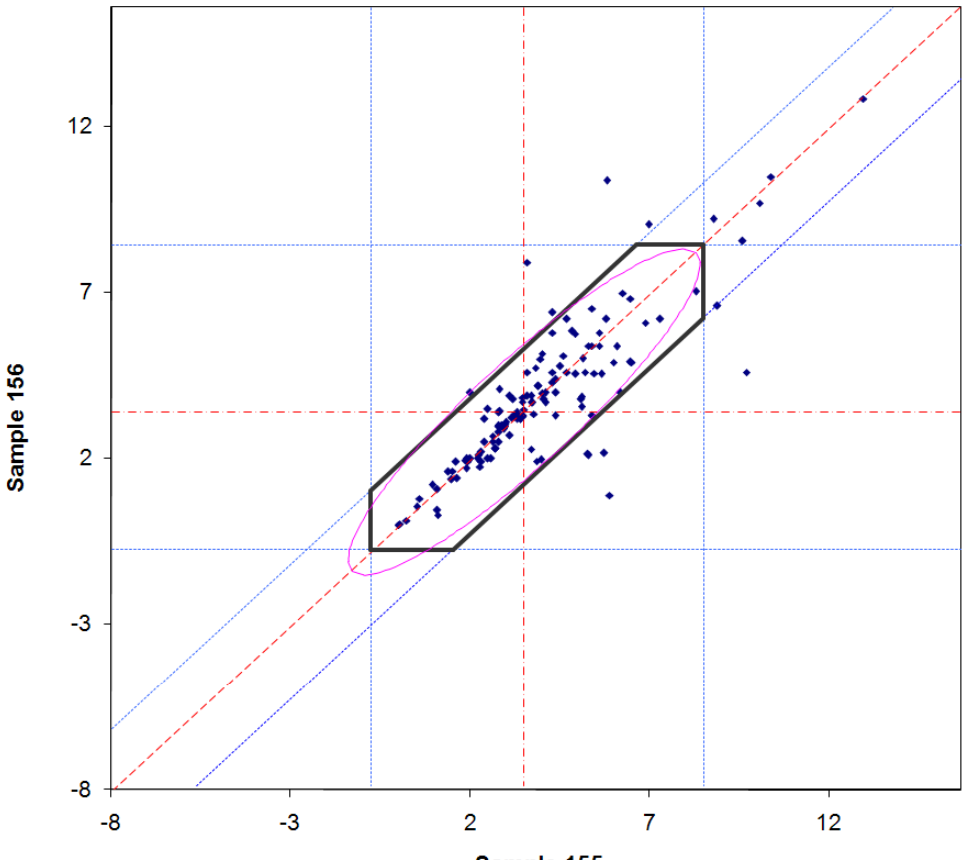
Reproducability (Sample 152)		
1s	d2s	CV%
1.576	4.457	49.07

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

143	Total Laboratories
8	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
123	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
3.510	3.409

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.495	1.400	14.10	14.51

Reproducability (Sample 155)		
1s	d2s	CV%
1.617	4.572	46.05

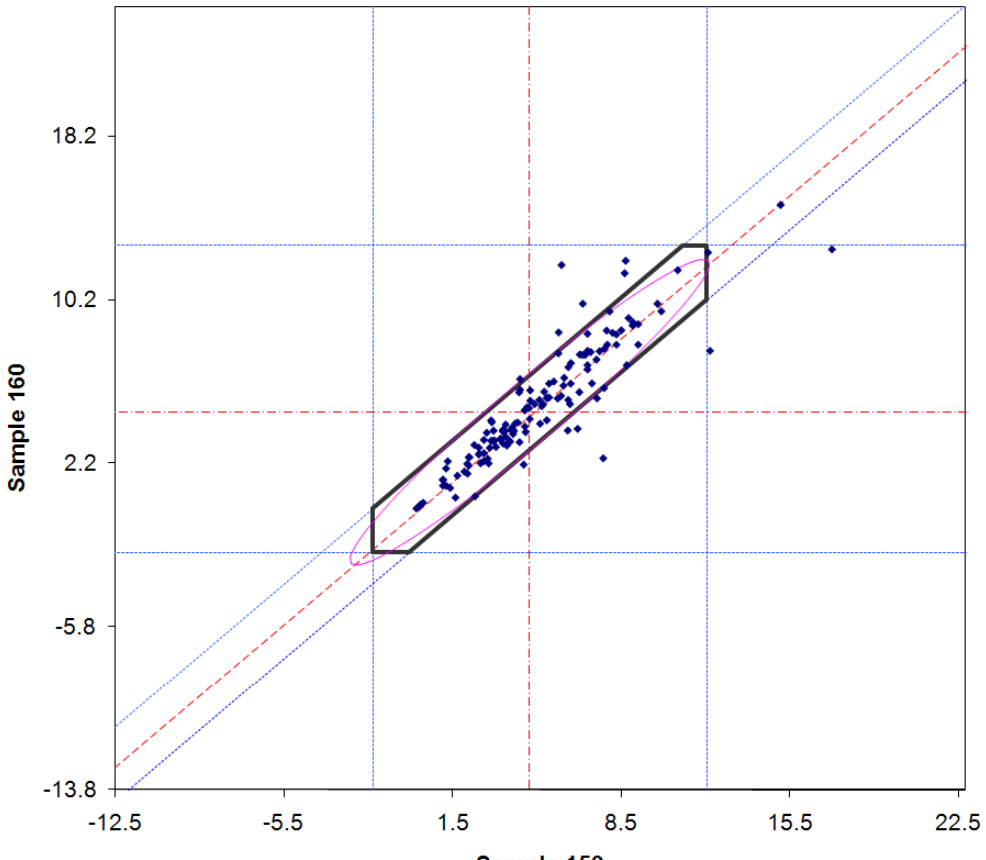
Reproducability (Sample 156)		
1s	d2s	CV%
1.578	4.464	46.29

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

139	Total Laboratories
6	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
121	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
4.693	4.724

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.450	1.272	9.58	9.52

Reproducability (Sample 159)		
1s	d2s	CV%
2.432	6.878	51.81

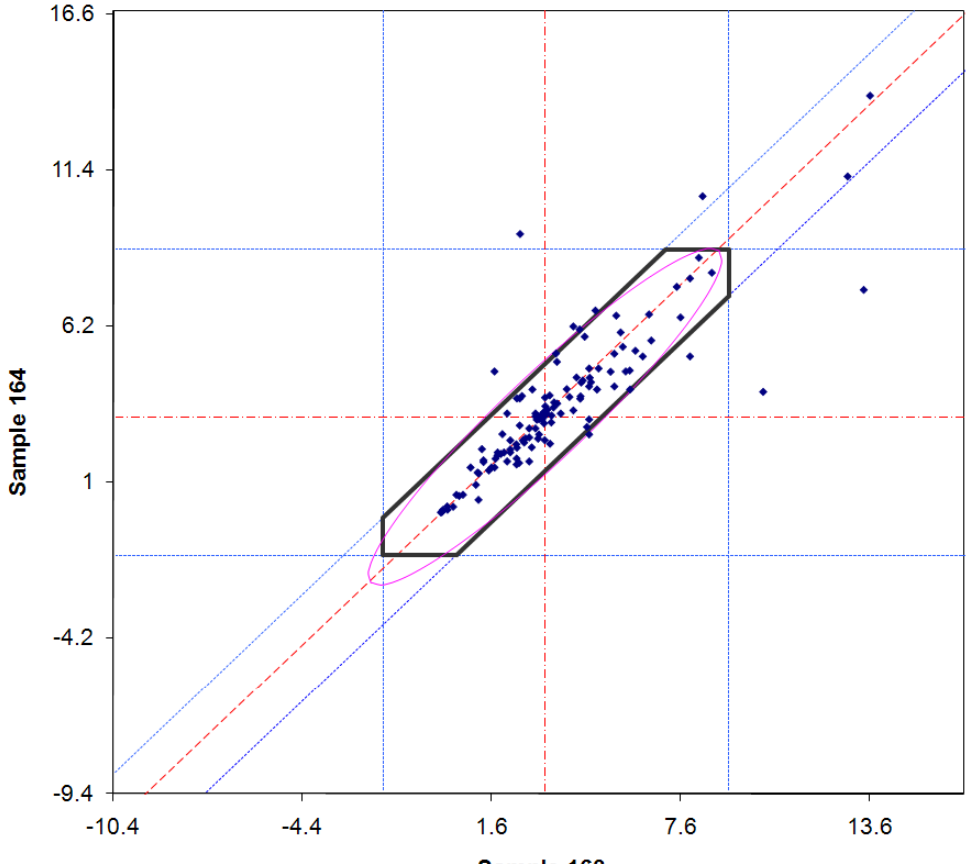
Reproducability (Sample 160)		
1s	d2s	CV%
2.516	7.116	53.25

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Soundness Test Using Magnesium Sulfate, Material Finer Than the 300 micron Sieve



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

133	Total Laboratories
11	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
112	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
3.307	3.183

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.458	1.296	13.86	14.40

Reproducability (Sample 163)		
1s	d2s	CV%
1.884	5.330	56.99

Reproducability (Sample 164)		
1s	d2s	CV%
1.797	5.083	56.45

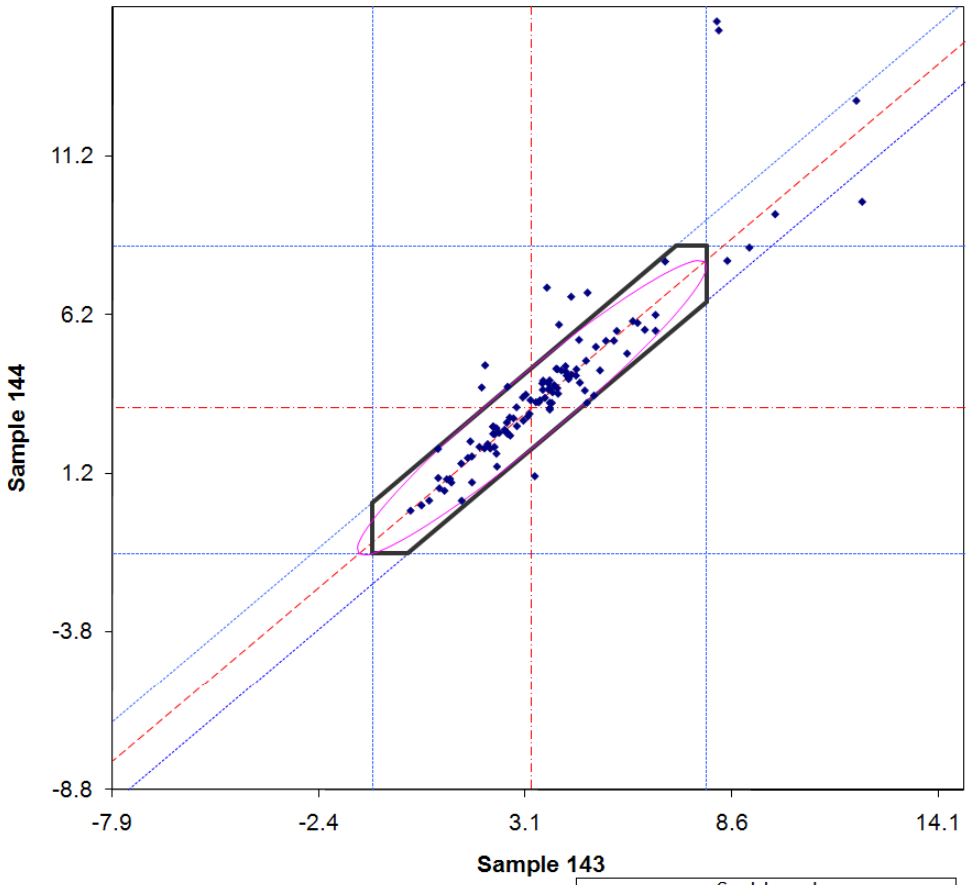
APPENDIX N: WEIGHTED AVERAGE SOUNDNESS MEASUREMENTS USING MAGNESIUM SULFATE, FINE AGGREGATE

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 143 and 144

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 143 and 144
Final Report Issued May 2004

Participation:

107	Total Laboratories
7	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
90	Total Laboratorires Included in Analysis

Average Results	
Sample 143 Average	Sample 144 Average
3.265	3.272

Repeatability			
1s	d2s	CV% (143)	CV% (144)
0.305	0.864	9.4	9.3

Reproducability (Sample 143)		
1s	d2s	CV%
1.531	4.331	46.9

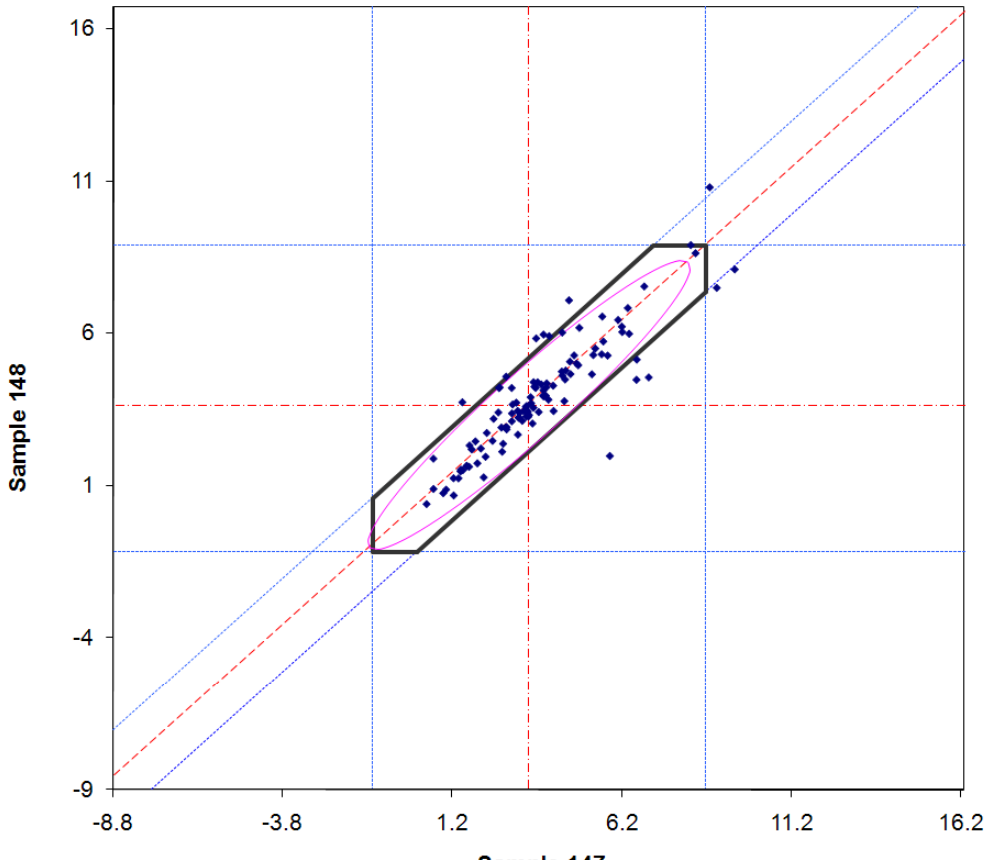
Reproducability (Sample 144)		
1s	d2s	CV%
1.545	4.369	47.2

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 147 and 148

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 147 and 148
Final Report Issued May 2005

Participation:

114	Total Laboratories
3	Laboratories Determined to be Invalid
13	Laboratories Determined to be Outliers
98	Total Laboratorires Included in Analysis

Average Results	
Sample 147 Average	Sample 148 Average
3.454	3.646

Repeatability			
1s	d2s	CV% (147)	CV% (148)
0.343	0.969	9.9	9.4

Reproducability (Sample 147)		
1s	d2s	CV%
1.530	4.326	44.3

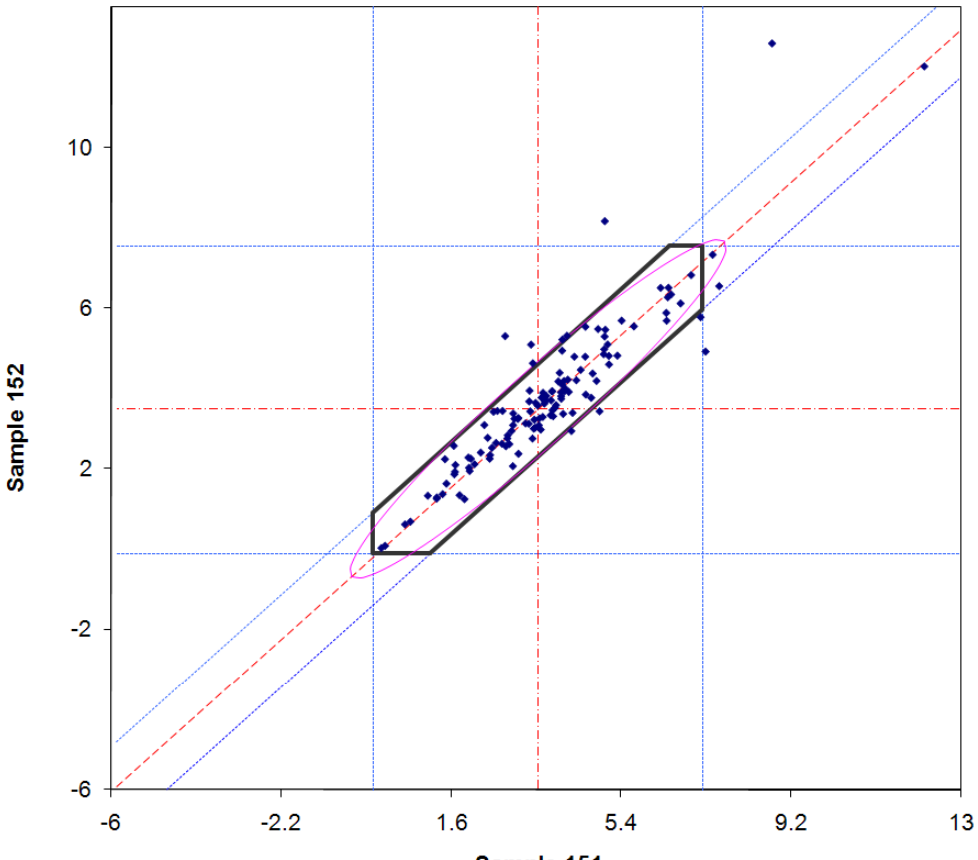
Reproducability (Sample 148)		
1s	d2s	CV%
1.595	4.511	43.7

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 151 and 152

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 151 and 152
Final Report Issued April 2006

Participation:

132	Total Laboratories
5	Laboratories Determined to be Invalid
9	Laboratories Determined to be Outliers
118	Total Laboratorires Included in Analysis

Average Results	
Sample 151 Average	Sample 152 Average
3.533	3.500

Repeatability			
1s	d2s	CV% (151)	CV% (152)
0.283	0.800	8.0	8.1

Reproducability (Sample 151)		
1s	d2s	CV%
1.413	3.998	40.0

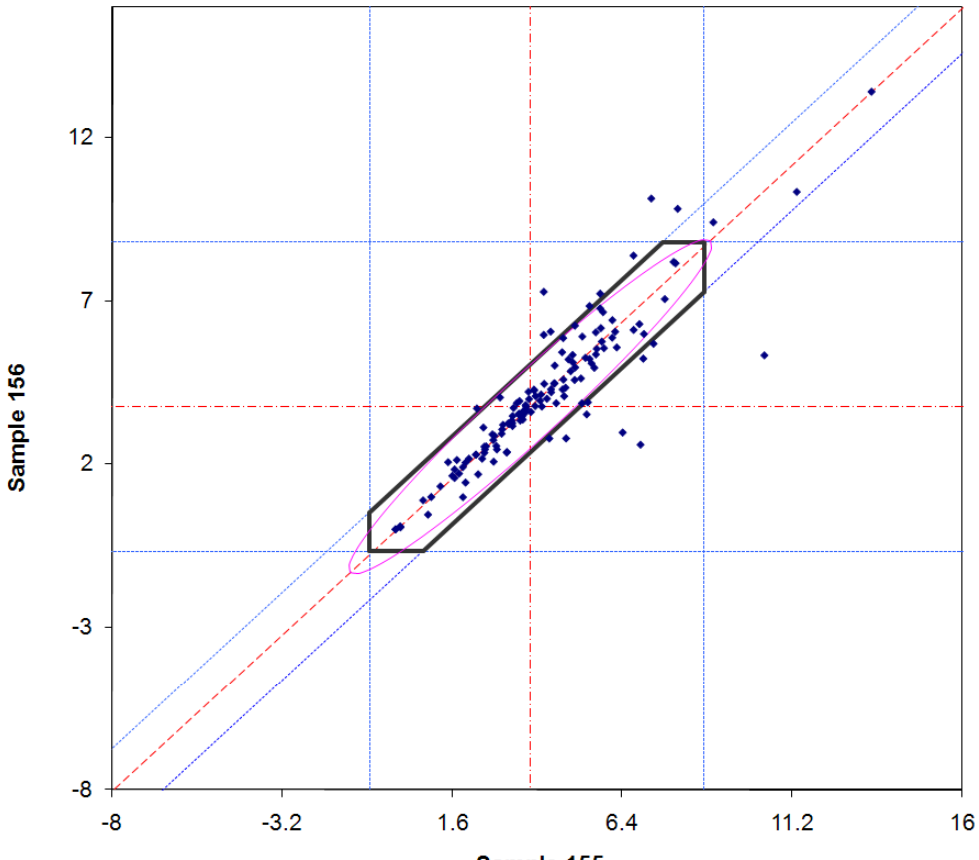
Reproducability (Sample 152)		
1s	d2s	CV%
1.365	3.861	39.0

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 155 and 156

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 155 and 156
Final Report Issued March 2007

Participation:

143	Total Laboratories
10	Laboratories Determined to be Invalid
16	Laboratories Determined to be Outliers
117	Total Laboratorires Included in Analysis

Average Results	
Sample 155 Average	Sample 156 Average
3.798	3.763

Repeatability			
1s	d2s	CV% (155)	CV% (156)
0.303	0.858	8.0	8.1

Reproducability (Sample 155)		
1s	d2s	CV%
1.680	4.752	44.2

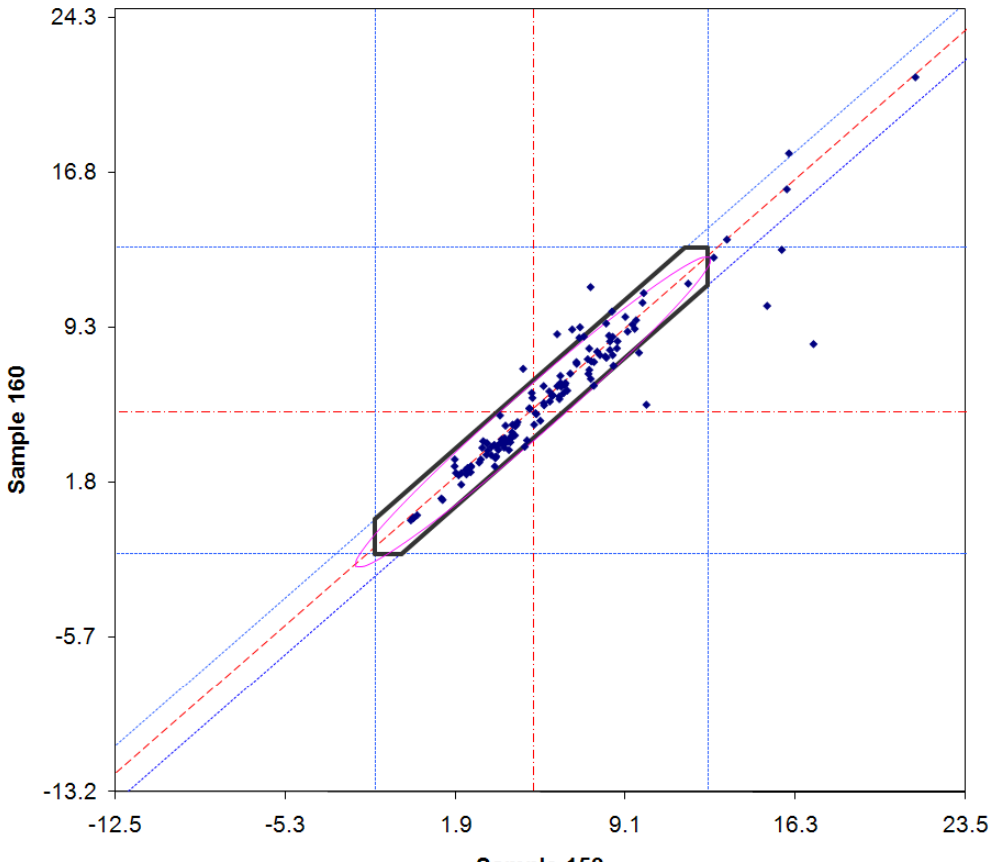
Reproducability (Sample 156)		
1s	d2s	CV%
1.706	4.826	45.3

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 159 and 160

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 159 and 160
Final Report Issued March 2008

Participation:

139	Total Laboratories
9	Laboratories Determined to be Invalid
12	Laboratories Determined to be Outliers
118	Total Laboratorires Included in Analysis

Average Results	
Sample 159 Average	Sample 160 Average
5.180	5.212

Repeatability			
1s	d2s	CV% (159)	CV% (160)
0.331	0.937	6.4	6.4

Reproducability (Sample 159)		
1s	d2s	CV%
2.471	6.990	47.7

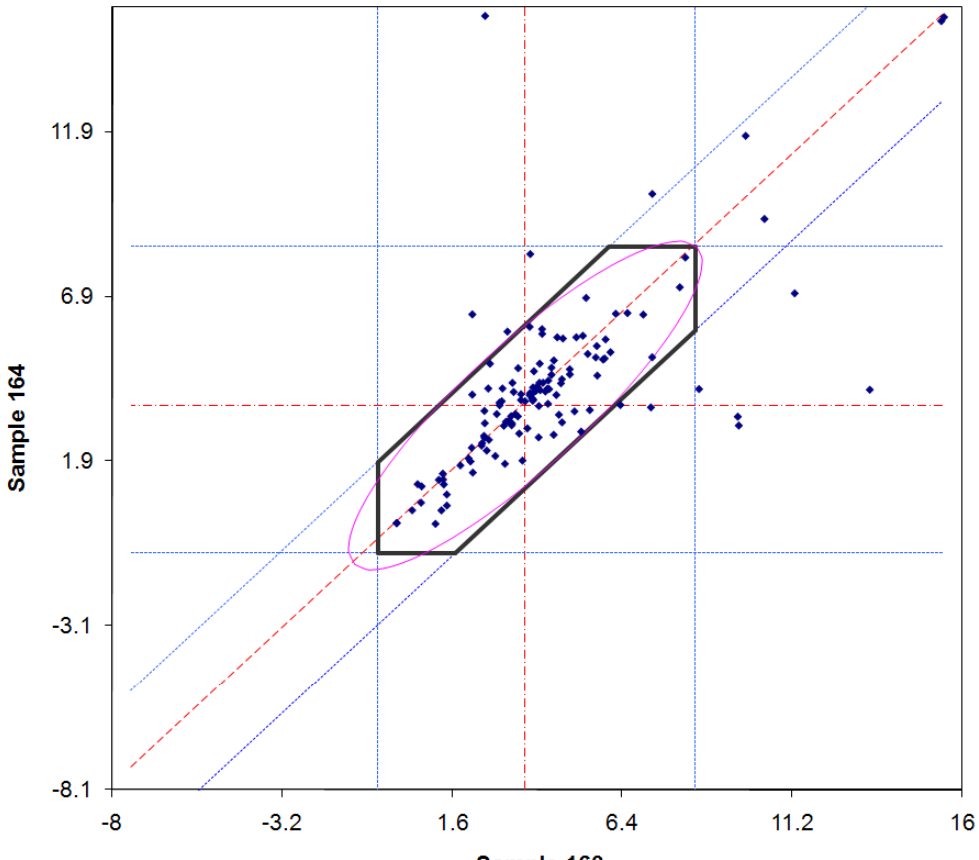
Reproducability (Sample 160)		
1s	d2s	CV%
2.520	7.127	48.3

Graph and Analysis Results for AASHTO T104

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AMRL Samples 163 and 164

Weighted Average Soundness Loss Using Magnesium Sulfate, Fine Aggregate



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 Samples 163 and 164
Final Report Issued March 2009

Participation:

132	Total Laboratories
9	Laboratories Determined to be Invalid
10	Laboratories Determined to be Outliers
113	Total Laboratorires Included in Analysis

Average Results	
Sample 163 Average	Sample 164 Average
3.659	3.607

Repeatability			
1s	d2s	CV% (163)	CV% (164)
0.594	1.679	16.2	16.5

Reproducability (Sample 163)		
1s	d2s	CV%
1.598	4.519	43.7

Reproducability (Sample 164)		
1s	d2s	CV%
1.617	4.573	44.8