Precision Estimates of AASHTO T 201, AASHTO T 202, and AASHTO T 49

DETAILS

25 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-28394-6 | DOI 10.17226/22392

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April 2014

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Research Results Digest 388

PRECISION ESTIMATES OF AASHTO T 201, AASHTO T 202, AND AASHTO T 49

NCHRP Project 10-87, Task Order #2

This digest presents results of Task Order #2 of NCHRP Project 10-87, "Precision Statements for AASHTO Standard Methods of Test." This work was conducted to update precision estimates of three test methods pertaining to asphalt binder: T 201, T 202, and T 49. Using the computed precision estimates, new precision statements for the three test methods have been prepared and are presented in this digest. The research was conducted by the AASHTO Materials Reference Laboratory. Dr. Haleh Azari was the Principal Investigator.

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CHAPTER 1—INTRODUCTION AND RESEARCH APPROACH

1.1 Background

Under NCHRP Project 10-87, the AASHTO Materials Reference Laboratory (AMRL) is conducting a multi-phase research project to improve estimates of precision in AASHTO test methods for a wide range of construction materials.

AMRL has an extensive database of test results for the broad range of construction materials collected through its proficiency sample program (PSP) that are used for developing the precision estimates (*1*). Laboratories participating in the AMRL PSP receive annual or biannual shipments of paired proficiency samples, which are tested according to specified AASHTO test methods. The results of the testing are returned to AMRL for analysis, summarization, and reporting back to the participating laboratories. The number of participants in the AMRL PSP program is sufficiently large to ensure a statistically sound basis for determination of estimates of precision for standard test methods.

The technique developed by AMRL in NCHRP Project 9-26 is used for analyzing proficiency sample data (*2*). This four-step statistical method removes outlying results and analyzes the core data of a paired data set. The results of the analysis can then be used to obtain reliable single-operator and multilaboratory estimates of precision. A summary of the analysis method is provided in Appendix A, which is not published herein, but can be found online at http://www.trb.org by searching for NCHRP Project 10-87.

NCHRP RRD 388 presents the results from Task 2 of NCHRP Project 10-87 where data from the PSP testing program of viscosity graded asphalt cement (VGAC) were used to update precision estimates for AASHTO Standard Test Methods T 201, "Kinematic Viscosity of Asphalts (Bitumens)"; T 202, "Viscosity of Asphalts by Vacuum Capillary Viscometer"; and T 49, "Penetration of Bituminous Materials" (*3*–*5*).

1.2 Research Objective

The objective of Task 2 of NCHRP Project 10-87 was to update the precision estimates of AASHTO T 201, T 202, and T 49.

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1.3 Scope of Study

The scope of the project included the following major activities:

1. Update precision estimates of AASHTO T 201, T 202, and T 49.
   a. Organize the most recent sets of PSP data collected according to each test method.
   b. Analyze the data for determining single-operator and multilaboratory estimates of precision.
   c. Compare the existing and new precision estimates for each test method.
2. Draw conclusions and prepare proposed precision statements for AASHTO T 201, T 202, and T 49.

1.4 Proficiency Samples Used in This Study

Data collected by AMRL on a wide range of materials tested according to AASHTO T 201, T 202, and T 49 were used to update the precision estimates of the three test methods. Only the most recent proficiency sample data were used to account for changes in precision estimates resulting from testing a wider range of materials and the effects of recent changes to the test methods. The researchers analyzed 168 sets of data, collected from the laboratories participating in the VGAC testing program of PSP. Table 1-1 provides information on the PSP sample rounds, which include the sample pair identification numbers, and the date the data was collected. Table 1-2 shows the number of data sets collected according to each test method on the original asphalt and rolling thin film oven (RTFO) residue at various temperatures. The sample instructions and data sheets sent to the laboratories for the VGAC testing program are provided in Appendix B, which is not published herein, but can be found online at http://www.trb.org by searching for NCHRP Project 10-87.

Table 1-1 List of 21 PSP rounds of viscosity graded asphalt cement (VGAC) samples for determining precision estimates of AASHTO T 201, T 202, and T 49.

Round #	PSP Sample No.	Date
1	233-234	Nov. 2013
2	231-232	May 2013
3	229-230	Nov. 2012
4	227-228	May 2012
5	225-226	Nov. 2011
6	223-224	May 2011
7	221-222	Nov. 2010
8	219-220	April 2010
9	217-218	Nov. 2009
10	215-216	April 2009
11	213-214	Nov. 2008
12	211-212	April 2008
13	209-210	Nov. 2007
14	207-208	April 2007
15	205-206	Nov. 2006
16	203-204	May 2006
17	201-202	Dec. 2005
18	199-200	May 2005
19	197-198	Dec. 2004
20	195-196	May 2004
21	193-194	Dec. 2003

Table 1-2 Number of PSP VGAC data sets used for determining precision estimates of AASHTO T 201, T 202, and T 49.

Test Method	Property Measured	Material	Test Temperature, °C	No. of Data Sets
AASHTO T 201	Kinematic viscosity	Original asphalt RTFO residue	135	42
AASHTO T 202	Viscosity by vacuum Capillary viscometer	Original asphalt RTFO residue	60	42
AASHTO T 49	Penetration	Original asphalt	4 25	42
		RTFO residue	4 25	42
Total no. of data sets				168

CHAPTER 2—ANALYSIS OF RESULTS

This chapter includes summaries of the data and the resulting precision estimates. The individual results for each of the 168 proficiency data sets analyzed in this study can be found in Appendixes C through E, which are not published herein, but can be found online at http://www.trb.org by searching for NCHRP Project 10-87. Using the most recent PSP data sets presented in Table 2-1, the precision estimates of T 201, T 202, and T 49 were updated. For each of the test methods, a summary of statistics of individual data sets used for the update of precision estimates as well as the pooled repeatability and reproducibility estimates are presented in the following sections.

2.1 Precision Estimates of T 201

AASHTO T 201-10 is identical to ASTM D 2170-10 (*6*) except for several provisions described in AASHTO T 201-10. The test method covers procedures for the determination of kinematic viscosity of liquid asphalts (bitumen) at 60°C and of asphalt cements at 135°C in the range of 6 to 100,000 mm²/s. A summary of statistics of the original and RTFO-aged kinematic viscosity of asphalt cements from the 21 most recent rounds of PSP VGAC program tested at 135°C according to AASHTO T 201 is provided in Table 2-1 and Table 2-2. The plots of the individual data pairs are found in Appendix C.

A review of the data in the tables, as presented in Figure 2-1 and Figure 2-2, suggests that there is a relationship between the repeatability/reproducibility standard deviations and the average for both original and RTFO binder ($R^2 = 0.43$ to 0.85). Meanwhile, there is no relationship between the average values and the repeatability or reproducibility coefficient of variation of the original asphalt (R^2 of 0.03 and 0.05) and a weak relationship between the average values and the coefficients of variation of the

Table 2-1 Summary of statistics for kinematic viscosity (AASHTO T 201) of 21 sets of original VGAC sample pairs.

		Average Results		Repeatability			Reproducibility			
							X Samples		Y Samples	
PSP Sample No.	No. of Labs	X mm²/s	Y mm²/s	1s mm²/s	X Samples CV%	Y Samples CV%	1s mm²/s	CV%	1s mm²/s	CV%
233-234	85	377.2	387.1	6.90	1.8	1.8	9.66	2.6	10.43	2.7
231-232	76	465.1	469.2	4.48	1.0	1.0	8.47	1.8	8.90	1.9
229-230	75	559.5	555.2	7.66	1.4	1.4	14.17	2.5	14.24	2.6
227-228	80	409.3	410.8	4.34	1.1	1.1	9.22	2.3	9.18	2.2
225-226	79	508.3	509.0	5.58	1.1	1.1	11.20	2.2	11.07	2.2
223-224	79	445.1	508.5	6.36	1.4	1.3	11.97	2.7	10.62	2.1
221-222	81	443.3	443.2	6.08	1.4	1.4	8.25	1.9	8.60	1.9
219-220	75	445.2	448.9	4.06	0.9	0.9	6.53	1.5	7.65	1.7
217-218	80	540.9	542.3	4.28	0.8	0.8	9.79	1.8	9.47	1.7
215-216	87	390.9	390.2	2.95	0.8	0.8	6.74	1.7	6.24	1.6
213-214	86	447.9	449.6	3.90	0.9	0.9	7.84	1.7	8.49	1.9
211-212	90	444.9	444.7	6.36	1.4	1.4	9.97	2.2	10.28	2.3
209-210	89	434.7	435.4	4.14	1.0	1.0	9.19	2.1	10.00	2.3
207-208	99	286.6	286.0	3.08	1.1	1.1	6.11	2.1	6.00	2.1
205-207	104	531.0	535.0	5.91	1.1	1.1	13.44	2.5	12.35	2.3
203-204	115	392.7	393.9	6.56	1.7	1.7	10.30	2.6	11.50	2.9
201-202	116	462.0	464.4	7.86	1.7	1.7	14.30	3.1	13.30	2.9
199-200	107	283.0	283.5	4.15	1.5	1.5	6.70	2.4	7.90	2.8
197-198	111	489.0	488.9	10.99	2.2	2.2	18.50	3.8	15.30	3.1
195-196	116	702.3	700.9	14.12	2.0	2.0	21.70	3.1	20.60	2.9
193-194	118	470.3	469.1	9.54	2.0	2.0	11.40	2.4	13.80	3.0

Table 2-2 Summary of statistics for kinematic viscosity (AASHTO T 201) of 21 sets of rolling thin film oven (RTFO) aged VGAC sample pairs.

		Average Results		Repeatability			Reproducibility			
							X Samples		Y Samples	
PSP Sample No.	No. of Labs	X mm²/s	Y mm²/s	1s mm²/s	X Samples CV%	Y Samples CV%	1s mm²/s	CV%	1s mm²/s	CV%
233-234	76	572.9	581.8	10.32	1.8	1.8	19.31	3.4	21.00	3.6
231-232	66	625.8	632.8	6.88	1.1	1.1	18.69	3.0	16.10	2.5
229-230	67	810.0	815.3	9.89	1.2	1.2	25.67	3.2	29.04	3.6
227-228	67	603.5	605.9	6.19	1.0	1.0	19.03	3.2	21.68	3.6
225-226	69	725.8	726.4	9.43	1.3	1.3	24.55	3.4	23.32	3.2
223-224	68	627.5	719.1	13.74	2.2	1.9	22.24	3.5	23.17	3.2
221-222	71	696.0	695.6	10.87	1.6	1.6	22.70	3.3	23.01	3.3
219-220	69	629.1	656.5	12.52	2.0	1.9	20.53	3.3	22.35	3.4
217-218	71	765.7	767.2	8.98	1.2	1.2	19.96	2.6	22.91	3.0
215-216	75	536.8	535.4	4.80	0.9	0.9	14.24	2.7	14.52	2.7
213-214	71	661.2	661.9	7.50	1.1	1.1	20.95	3.2	23.44	3.5
211-212	76	632.0	629.7	8.64	1.4	1.4	19.13	3.0	17.02	2.7
209-210	78	700.3	704.5	10.20	1.5	1.4	26.60	3.8	27.58	3.9
207-208	83	429.6	428.7	4.77	1.1	1.1	11.21	2.6	10.74	2.5
205-207	89	1,007.7	1,017.9	19.22	1.9	1.9	48.91	4.9	54.86	5.4
203-204	96	556.9	557.1	9.59	1.7	1.7	18.70	3.4	16.40	2.9
201-202	99	911.9	913.4	31.01	3.4	3.4	48.70	5.3	53.10	5.8
199-200	99	430.0	431.9	8.47	2.0	2.0	15.50	3.6	16.50	3.8
197-198	99	856.1	854.9	23.11	2.7	2.7	42.50	5.0	41.80	4.9
195-196	98	1,036.5	1,035.3	28.10	2.7	2.7	46.10	4.5	50.20	4.9
193-194	98	671.0	672.5	16.54	2.5	2.5	23.80	3.6	30.20	4.5

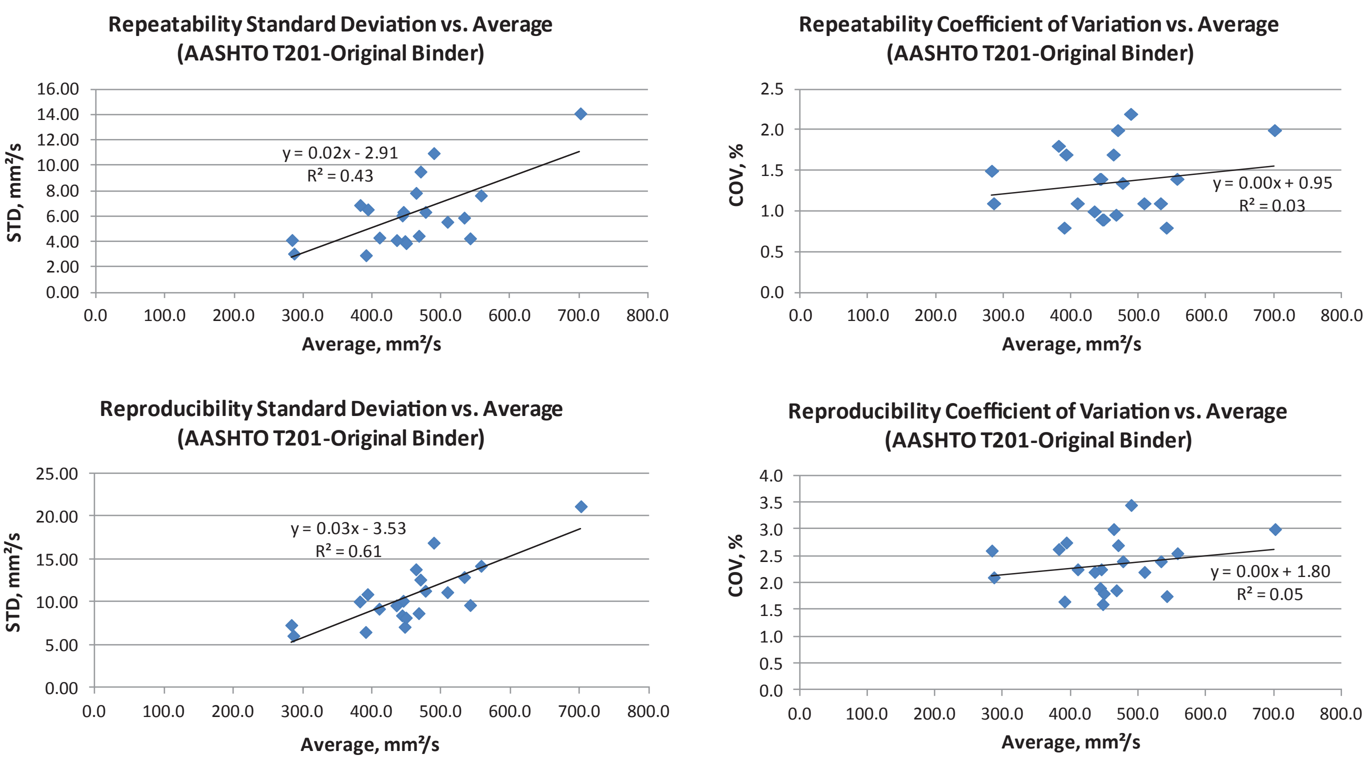

Figure 2-1 Relationship between average and standard deviation and between average and coefficient of variation of kinematic viscosity (AASHTO T 201) test results for original asphalt.

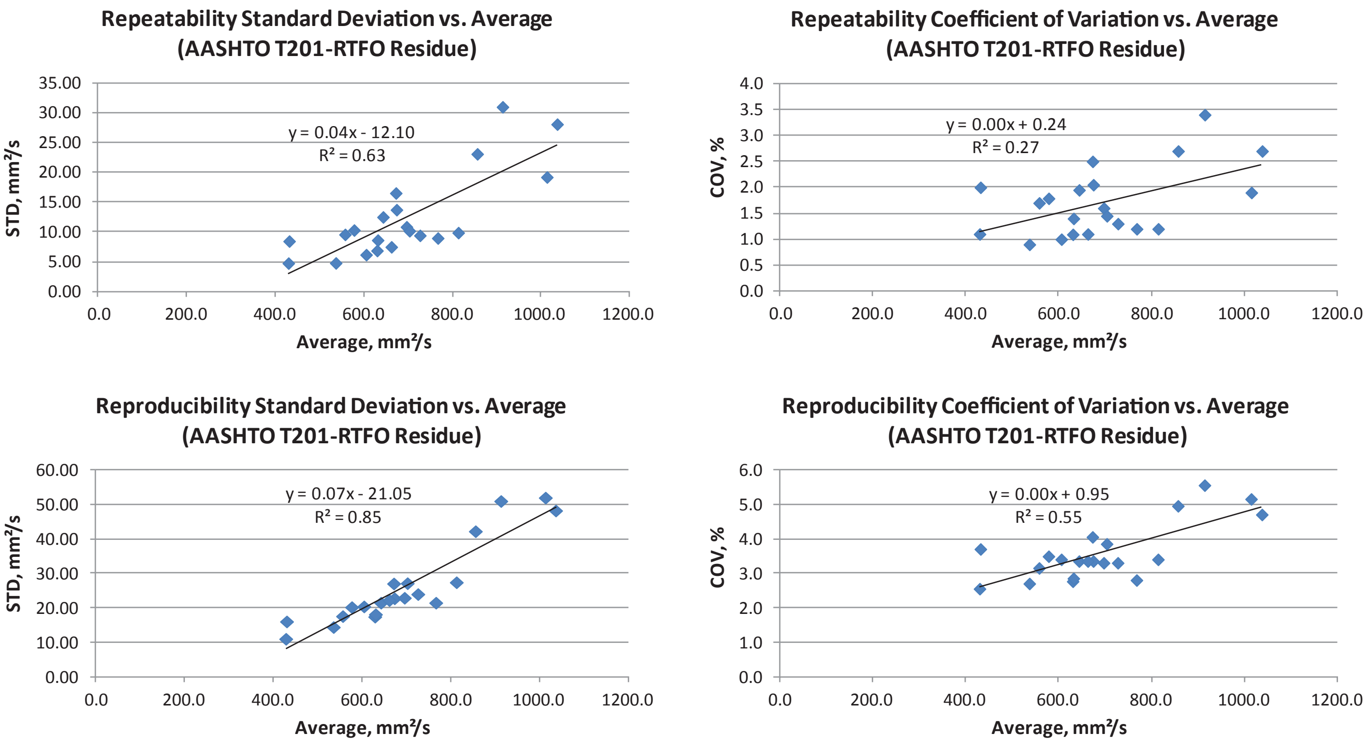

Figure 2-2 Relationship between average and standard deviation and between average and coefficient of variation of kinematic viscosity (AASHTO T 201) test results for RTFO residue.

RTFO residue (R^2 of 0.27 and 0.55). Therefore, as specified in ASTM C 670 (*7*), the form of the precision estimates would be based on the sample coefficient of variation. The repeatability and reproducibility estimates of precision for the original and RTFO samples were then computed by averaging the coefficients of variation of the individual samples in Table 2-1 and Table 2-2, respectively. The resulting precision estimates of AASHTO T 201 for the original and RTFO asphalts are provided in Table 2-3.

2.1.1 Comparison of the New and Existing Precision Estimates of AASHTO T 201

The precision statement of ASTM D 2170-10 does not provide separate precisions for the kinematic viscosity of the original and RTFO asphalt binders. The existing precision statement provides single-operator and multilaboratory coefficients of variation for kinematic viscosity of asphalt cement at 135°C, which are shown in parentheses in Table 2-3. As indicated from the table, the new single-operator

Table 2-3 Pooled repeatability and reproducibility precisions of T 201 based on samples' coefficient of variation; the values in parentheses represent the current precision estimates in ASTM D 2170-10.

Asphalt	Statistics	1s (%)	d2s (%)
Original	Repeatability	1.3 (0.64)	3.8 (1.8)
	Reproducibility	2.3 (3.1)	6.6 (8.8)
RTFO (average of kinematic viscosity < 850 mm²/s)	Repeatability	1.5 (0.64)	4.2 (1.8)
	Reproducibility	3.3 (0.64)	9.2 (1.8)
RTFO (average of kinematic viscosity ≥ 850 mm²/s)	Repeatability	2.7 (3.1)	7.6 (8.8)
	Reproducibility	5.1 (3.1)	14.4 (8.8)

coefficient of variation for the original asphalt is 1.3% and for the RTFO residue is 1.7%. These values are significantly larger than the existing single-operator coefficient of variation of 0.64% for kinematic viscosity of asphalt cement at 135°C in ASTM D 2170-10.

The new multilaboratory coefficient of variation for the original asphalt is 2.3% and for the RTFO residue is 3.6%. These values are compared with the existing multilaboratory coefficient of variation of 3.1% for kinematic viscosity of asphalt cement at 135°C. The new estimates of precision for kinematic viscosity of the original and RTFO asphalt binders are 25.8% smaller and 16.1% larger than the existing multilaboratory coefficient of variation, respectively.

The reason for the significant difference in repeatability coefficient of variation is not clear since the range of kinematic viscosity values used for computing the existing precisions in ASTM D 2170-10 is not known. However, the difference between the existing and new reproducibility coefficients of variation can be attributed to computing separate coefficients of variation for the original asphalt and RTFO residue and to the fact that the variability of the RTFO test (AASHTO T 240) is also included in the variability of the viscosity measurements. The average of the two multilaboratory coefficients of variation (3.0%) seems to be comparable with the existing multilaboratory coefficient of variation of 3.1%.

2.2 Precision Estimates of T 202

AASHTO T 202-10 is identical to ASTM D 2171-10 (*8*) except for several provisions described in AASHTO T 202-10. The test method covers procedures for the determination of the viscosity of asphalt binder (bitumen) by vacuum capillary viscometers at 60°C. The test method is applicable to materials having viscosities in the range of 0.0036 to greater than 20,000 Pa s. A summary of statistics of the original and RTFO-aged viscosity by vacuum capillary of the 21 most recent pairs of PSP VGAC samples determined according to AASHTO T 202 is provided in Table 2-4 and Table 2-5. The plots of the individual data sets are found in Appendix D.

Table 2-4 Summary of statistics for viscosity of asphalt by vacuum capillary viscometer (AASHTO T 202) of 21 sets of original VGAC sample pairs.

				Repeatability			Reproducibility			
		Average Results					X Samples		Y Samples	
PSP Sample No.	No. of Labs	X (Pa.s)	Y (Pa.s)	1s (Pa.s)	X Samples CV%	Y Samples CV%	1s (Pa.s)	CV%	1s (Pa.s)	CV%
233-234	114	203.5	216.6	4.21	2.1	1.9	6.33	3.1	6.77	3.1
231-232	111	263.3	268.0	3.79	1.4	1.4	7.39	2.8	8.16	3.0
229-230	107	310.0	298.3	6.63	2.1	2.2	8.56	2.8	10.48	3.5
227-228	102	228.4	229.0	1.95	0.9	0.8	5.94	2.6	6.13	2.7
225-226	98	304.0	303.9	2.81	0.9	0.9	7.55	2.5	7.24	2.4
223-224	94	210.2	301.7	3.35	1.6	1.1	4.84	2.3	7.29	2.4
221-222	104	225.7	224.6	2.19	1.0	1.0	6.68	3.0	7.05	3.1
219-220	107	210.2	214.7	2.75	1.3	1.3	6.01	2.9	7.27	3.4
217-218	105	340.5	341.7	3.09	0.9	0.9	7.32	2.1	7.92	2.3
215-216	109	178.8	179.0	1.51	0.8	0.8	3.90	2.2	3.94	2.2
213-214	100	214.0	214.3	2.01	0.9	0.9	6.53	3.1	6.71	3.1
211-212	111	211.1	209.2	2.67	1.3	1.3	5.44	2.6	5.53	2.6
209-210	113	416.9	420.8	5.97	1.4	1.4	12.21	2.9	12.22	2.9
207-208	107	102.3	101.3	1.01	1.0	1.0	1.96	1.9	2.11	2.1
205-207	128	309.8	316.8	4.60	1.5	1.5	11.29	3.6	11.66	3.7
203-204	133	1,941.0	1,948.6	29.58	1.5	1.5	59.00	3.0	61.40	3.2
201-202	131	2,153.3	2,145.3	39.41	1.8	1.8	101.60	4.7	92.70	4.3
199-200	128	955.9	959.8	22.39	2.3	2.3	32.20	3.4	36.40	3.8
197-198	135	2,232.8	2,266.1	60.57	2.7	2.7	118.70	5.3	110.60	4.9
195-196	130	5,930.7	5,919.6	144.45	2.4	2.4	202.70	3.4	221.00	3.7
193-194	130	2,282.4	2,278.2	32.26	1.4	1.4	80.90	3.5	86.30	3.8

Table 2-5 Summary of statistics for viscosity of asphalts by vacuum capillary viscometer (AASHTO T 202) of 21 sets of RTFO-aged sample pairs.

				Repeatability			Reproducibility			
PSP Sample No.	No. of Labs	Average Results			X Samples	Y Samples	X Sample		X Sample	
		X (Pa.s)	Y (Pa.s)	1s (Pa.s)	CV%	CV%	1s (Pa.s)	CV%	1s (Pa.s)	CV%
233-234	100	537.8	556.1	19.05	3.5	3.4	28.57	5.3	29.08	5.2
231-232	93	532.1	540.5	10.76	2.0	2.0	25.56	4.8	24.00	4.4
229-230	91	749.7	758.6	13.91	1.9	1.8	42.19	5.6	43.80	5.8
227-228	93	528.6	534.6	10.67	2.0	2.0	30.60	5.8	29.93	5.6
225-226	87	694.1	702.4	15.24	2.2	2.2	38.43	5.5	40.74	5.8
223-224	86	480.7	699.2	17.87	3.7	2.6	29.50	6.1	44.31	6.3
221-222	91	604.6	602.4	12.99	2.1	2.2	39.32	6.5	39.97	6.6
219-220	94	484.2	561.1	24.68	5.1	4.4	33.08	6.8	49.52	8.8
217-218	92	765.8	763.5	11.77	1.5	1.5	38.99	5.1	39.34	5.2
215-216	87	403.5	404.1	6.09	1.5	1.5	21.32	5.3	21.22	5.3
213-214	88	567.7	566.2	10.03	1.8	1.8	34.85	6.1	34.34	6.1
211-212	92	478.2	474.8	8.57	1.8	1.8	24.30	5.1	25.14	5.3
209-210	92	1,200.5	1,209.5	29.12	2.4	2.4	87.26	7.3	87.55	7.2
207-208	94	264.6	261.9	6.94	2.6	2.6	18.14	6.9	15.97	6.1
205-207	106	1,477.4	1,497.9	48.79	3.3	3.3	145.30	9.8	154.49	10.3
203-204	115	4,690.6	4,683.6	140.22	3.0	3.0	318.80	6.8	303.90	6.5
201-202	115	10,120.1	10,105.7	379.67	3.8	3.8	1,133.00	11.2	1,092.70	10.8
199-200	116	2,544.0	2,546.7	75.80	3.0	3.0	202.40	8.0	194.90	7.7
197-198	114	7,450.5	7,493.7	224.97	3.0	3.0	652.70	8.8	671.60	9.0
195-196	109	11,585.7	11,554.9	477.46	4.1	4.1	852.00	7.4	884.10	7.7
193-194	105	5,927.3	5,964.6	203.62	3.4	3.4	459.00	7.7	436.50	7.3

A review of the data in Table 2-4 and Table 2-5, as presented in Figure 2-3 and Figure 2-4, suggests that there are relationships between the standard deviations and the average viscosity values. Meanwhile, there are weak relationships between the average values and the repeatability or reproducibility coefficient of variations. Therefore, the form of the precision estimates would be based on the sample coefficient of variation. The repeatability and reproducibility estimates of precision were then computed by averaging the coefficient of variations of the individual samples in Table 2-4 and Table 2-5. The resulted precision estimates of the AASHTO T 202 are provided in Table 2-6.

2.2.1 Comparison of the New and Existing Precision Estimates of AASHTO T 202

The precision statement of ASTM D 2171-10 does not provide separate precisions for the viscosity by vacuum capillary of the original and RTFO asphalt binders. The existing statement provides d2s single-operator and multilaboratory coefficients of variation for viscosity by vacuum capillary at 60°C. These values are shown in parentheses in Table 2-6. The existing allowable difference between two replicate results is 7% of the mean. However, the new single-operator allowable difference between two replicate results is 4.1% of the mean for the original binder and 7.6% of the mean for the RTFO residue. The comparison of the existing and new precisions indicates a decrease of 39.4% (corresponding to original asphalt) and increase of 8.6% (corresponding to RTFO residue) in the single-operator coefficient of variation of viscosity by vacuum capillary.

For multilaboratory precision, the existing ASTM statement sets the allowable difference between the results of two laboratories as 10% of the mean. However, the new precision estimates, broken into viscosity of original asphalt and RTFO residue, set the allowable difference between two laboratories' results as 7.6% of the mean for the original asphalt and 19.0% of the mean for the RTFO residue. This is a decrease of 13.3% (corresponding to original asphalt)

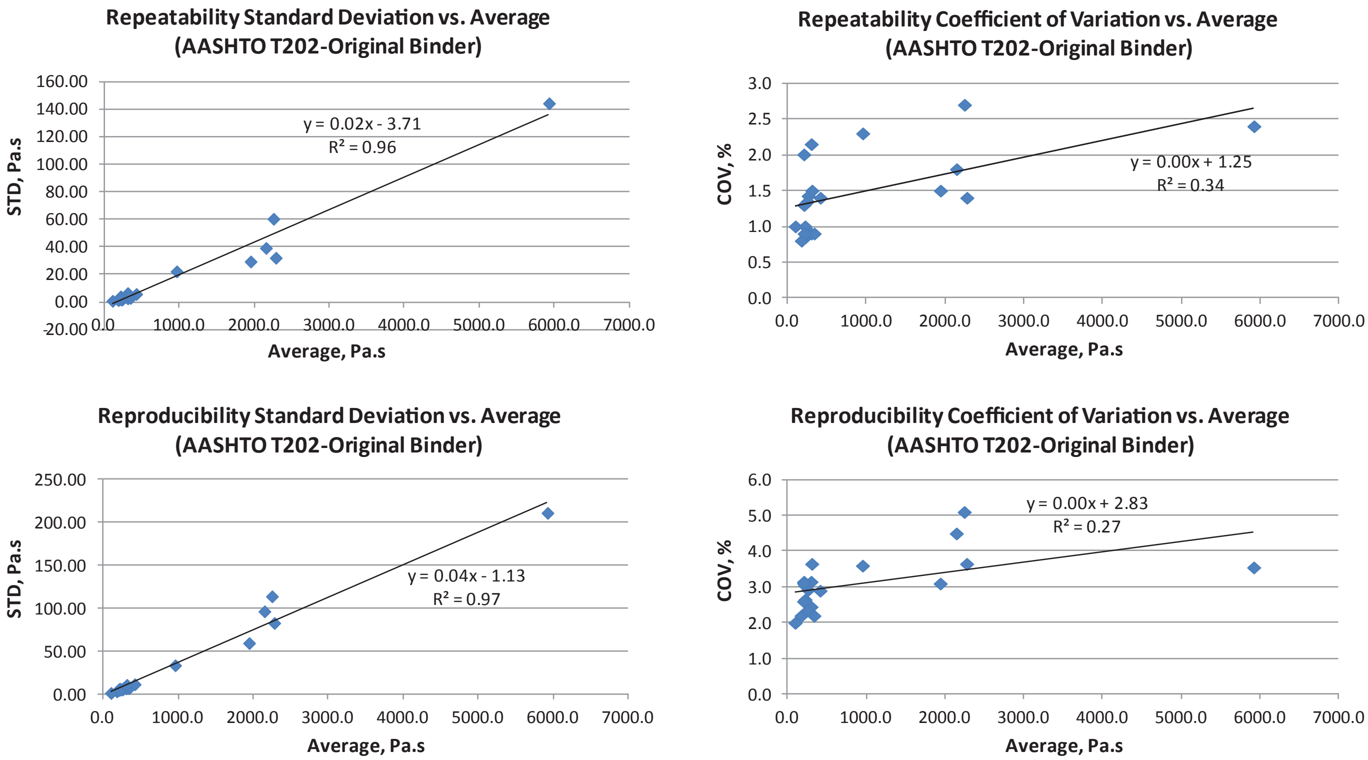

Figure 2-3 Relationship between averages and standard deviations and between averages and coefficients of variation of the viscosity of asphalts by vacuum capillary viscometer of original asphalt (AASHTO T 202) test method.

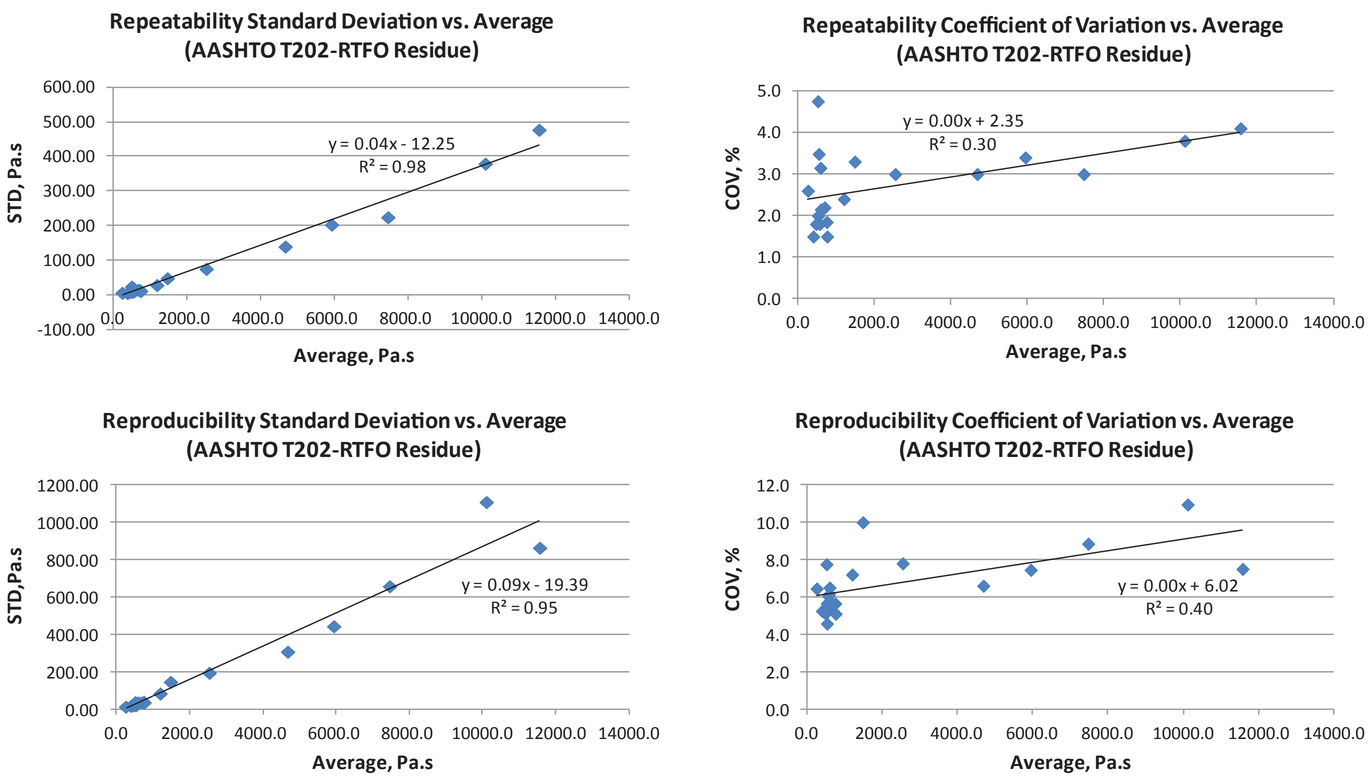

Figure 2-4 Relationship between averages and standard deviations and between averages and coefficients of variation of the viscosity of asphalt by vacuum capillary viscometer of RTFO residue (AASHTO T 202) test method.

Table 2-6 Pooled repeatability and reproducibility precisions of T 202 based on samples' coefficient of variation.

Asphalt	Statistics	1s (%)	d2s (%)
Original	Repeatability	1.5	4.2 (7)
	Reproducibility	3.1	8.8 (10)
RTFO	Repeatability	2.7	7.7 (7)
	Reproducibility	6.8	19.2 (10)

and increase of 89% (corresponding to RTFO residue) in the multilaboratory coefficient of variation of viscosity by vacuum capillary.

The reason for the significant difference in repeatability coefficients of variation is not clear since the range of viscosity by vacuum capillary values used for computing the existing estimates of precision is not known. However, the differences between the existing and new reproducibility coefficients of variation could be attributed to computing separate coefficients of variation for the original asphalt and RTFO residue and the fact that the variability of the RTFO test (AASHTO T 240) is added to the variability of viscosity measurements.

2.3 Precision Estimates of T 49

AASHTO T 49-07 is identical to ASTM D 5-06 (*9*) except for several provisions described in AASHTO T 49-07. The test method covers determination of the penetration of semi-solid and solid bituminous materials. The conditions described in the test method provide for the determinations of penetrations up to 500 units. A summary of statistics of penetration of the original asphalt and RTFO residue from the 19 most recent PSP VGAC sample pairs tested at 4°C and 25°C according to T 49 is provided in Table 2-7 through Table 2-10. The plots of the individual data sets are found in Appendix E.

A review of the data in Tables 2-7 through 2-10, as presented in Figure 2-5 though Figure 2-8, indicates

Table 2-7 Summary of statistics for penetration (AASHTO T 49) of original asphalts at 4°C of 21 sets of VGAC sample pairs.

PSP Sample No.	No. of Labs	Average Results		Repeatability			Reproducibility			
							X Samples		Y Samples	
		X, Units	Y, Units	1s, Units	X Samples CV%	Y Samples CV%	1s, Units	CV%	1s, Units	CV%
233-234	90	21.5	20.7	1.09	5.1	5.3	3.24	15.1	3.46	16.8
231-232	81	18.6	18.4	0.74	4.0	4.0	2.86	15.3	2.98	16.2
229-230	85	20.3	20.3	1.12	5.5	5.5	2.76	13.6	2.85	14.1
227-228	77	28.0	28.2	0.95	3.4	3.4	3.86	13.8	3.71	13.1
225-226	80	18.8	18.6	0.89	4.7	4.8	3.00	15.9	2.87	15.4
223-224	71	24.1	19.3	1.67	6.9	8.6	4.18	17.3	3.75	19.5
221-222	79	30.7	30.9	0.88	2.9	2.8	3.72	12.1	3.63	11.7
219-220	75	23.1	24.0	0.95	4.1	4.0	3.25	14.0	3.15	13.1
217-218	78	18.7	18.8	0.60	3.2	3.2	3.11	16.6	3.06	16.3
215-216	75	22.0	22.0	0.62	2.8	2.8	2.80	12.7	2.61	11.9
213-214	79	23.8	23.8	0.65	2.7	2.7	3.21	13.5	3.15	13.2
211-212	82	23.3	23.4	0.71	3.0	3.0	3.17	13.6	3.04	13.0
209-210	89	11.7	11.8	0.57	4.9	4.9	2.71	23.1	2.68	22.8
207-208	84	39.3	39.6	0.86	2.2	2.2	4.02	10.2	3.98	10.1
205-207	90	28.6	28.6	0.83	2.9	2.9	3.48	12.2	3.48	12.2
203-204	92	19.1	19.0	1.07	5.6	5.7	3.60	19.0	3.90	20.4
201-202	89	42.3	42.3	0.94	2.2	2.2	4.40	10.5	4.60	10.8
199-200	91	43.8	44.0	1.25	2.9	2.9	5.00	11.4	5.20	11.9
197-198	94	34.3	34.3	0.99	2.9	2.9	3.70	10.9	3.70	10.7
195-196	97	16.7	16.5	0.92	5.5	5.5	3.10	18.7	3.10	18.7
193-194	93	21.1	20.8	1.04	4.9	5.0	3.20	15.2	3.10	14.7

Table 2-8 Summary of statistics for penetration (AASHTO T 49) of RTFO-aged asphalts at 4°C of 21 sets of VGAC sample pairs.

PSP Sample No.	No. of Labs	Average Results		Repeatability			Reproducibility			
					X Samples	Y Samples	X Samples		Y Samples	
		X, Units	Y, Units	1s, Units	CV%	CV%	1s, Units	CV%	1s, Units	CV%
233-234	85	14.8	14.3	0.92	6.2	6.4	2.40	16.2	2.47	17.3
231-232	74	14.1	14.2	0.77	5.4	5.4	2.64	18.7	2.47	17.3
229-230	71	14.7	15.0	0.69	4.7	4.6	1.74	11.8	1.76	11.7
227-228	68	20.6	20.8	0.59	2.9	2.8	2.30	11.1	2.35	11.3
225-226	72	13.9	14.0	0.76	5.5	5.5	2.22	15.9	2.24	16.0
223-224	64	17.3	13.9	1.24	7.2	8.9	2.15	12.4	2.40	17.3
221-222	68	21.5	21.4	0.79	3.7	3.7	2.65	12.4	2.59	12.1
219-220	66	17.4	17.5	0.91	5.2	5.2	2.27	13.0	2.06	11.8
217-218	72	14.3	14.3	0.63	4.4	4.4	2.87	20.1	2.86	20.1
215-216	68	16.2	16.1	0.55	3.4	3.4	2.55	15.7	2.27	14.0
213-214	77	17.3	17.3	0.65	3.7	3.8	3.06	17.7	2.89	16.7
211-212	75	17.2	17.2	0.59	3.4	3.4	2.68	15.5	2.77	16.1
209-210	79	7.9	7.8	0.55	6.9	7.0	2.26	28.7	2.15	27.6
207-208	78	25.9	26.2	1.04	4.0	4.0	2.85	11.0	2.87	11.0
205-207	84	19.5	19.5	0.81	4.2	4.2	2.18	11.2	2.07	10.6
203-204	87	13.8	13.9	0.81	5.9	5.9	3.10	22.4	2.90	20.9
201-202	86	27.2	26.8	1.33	4.9	5.0	4.00	14.8	3.70	13.7
199-200	87	26.8	26.9	1.07	4.0	4.0	3.90	14.7	4.10	15.1
197-198	87	21.8	21.8	0.77	3.5	3.5	2.50	11.5	2.80	12.6
195-196	85	14.0	14.0	0.77	5.5	5.5	3.10	21.9	3.10	21.9
193-194	78	16.1	16.1	0.84	5.2	5.2	2.40	15.0	2.50	15.4

Table 2-9 Summary of statistics for penetration (AASHTO T 49) of original asphalts at 25°C of 21 sets of VGAC sample pairs.

PSP Sample No.	No. of Labs	Average Results		Repeatability			Reproducibility			
					X Samples	Y Samples	X Samples		Y Samples	
		X, Units	Y, Units	1s, Units	CV%	CV%	1s, Units	CV%	1s, Units	CV%
233-234	153	63.8	61.4	1.70	2.7	2.8	3.31	5.2	3.23	5.3
231-232	141	55.2	54.9	0.88	1.6	1.6	3.17	5.7	3.26	5.9
229-230	137	55.5	56.1	1.06	1.9	1.9	2.41	4.4	2.60	4.6
227-228	141	74.0	73.5	1.34	1.8	1.8	2.76	3.7	2.94	4.0
225-226	132	51.9	52.0	1.02	2.0	2.0	2.69	5.2	2.81	5.4
223-224	126	68.2	52.7	1.83	2.7	3.5	4.11	6.0	3.60	6.8
221-222	123	81.7	82.2	0.87	1.1	1.1	3.25	4.0	3.12	3.8
219-220	132	68.9	70.3	1.39	2.0	2.0	3.19	4.6	3.16	4.5
217-218	127	49.6	49.6	0.70	1.4	1.4	2.86	5.8	2.93	5.9
215-216	138	65.6	65.7	1.11	1.7	1.7	3.26	5.0	3.24	4.9
213-214	135	70.9	71.0	0.81	1.1	1.1	3.81	5.4	3.75	5.3
211-212	139	68.0	68.4	0.96	1.4	1.4	3.49	5.1	3.35	4.9
209-210	138	33.4	33.5	0.86	2.6	2.6	2.50	7.5	2.78	8.3
207-208	140	116.1	116.7	1.34	1.2	1.1	4.98	4.3	4.94	4.2
205-207	147	68.0	67.5	0.99	1.5	1.5	2.79	4.1	2.82	4.2

Table 2-9 (Continued)

PSP Sample No.	No. of Labs	Average Results		Repeatability			Reproducibility			
							X Samples		Y Samples	
		X, Units	Y, Units	1s, Units	X Samples CV%	Y Samples CV%	1s, Units	CV%	1s, Units	CV%
203-204	156	54.9	54.8	1.67	3.0	3.0	3.30	6.1	3.30	6.0
201-202	154	92.6	92.4	1.79	1.9	1.9	4.80	5.2	4.80	5.2
199-200	152	128.9	128.7	2.09	1.6	1.6	6.60	5.1	6.30	4.9
197-198	153	88.9	88.6	1.42	1.6	1.6	3.70	4.2	3.40	3.8
195-196	157	39.5	39.7	1.39	3.5	3.5	3.40	8.5	3.40	8.4
193-194	164	56.2	56.4	1.42	2.5	2.5	3.50	6.2	3.60	6.5

that there could be moderate to strong relationships between the average and both the standard deviations and coefficients of variation. According to ASTM C 670 (*7*), since both standard deviation and coefficient of variation are functions of the average value, the equation of the lines of best fit to the averages and standard deviations would be used for determining the precision estimates. The resulting precision estimates of AASHTO T 49 are provided in Table 2-11.

2.3.1 Comparison of the New and Existing Precision Estimates of AASHTO T 49

The existing precision statement in ASTM D5-06 includes six single-operator and multilaboratory

Table 2-10 Summary of statistics for penetration (AASHTO T 49) of RTFO asphalt at 25°C of 21 sets of VGAC sample pairs.

PSP Sample No.	No. of Labs	Average Results		Repeatability			Reproducibility			
							X Samples		Y Samples	
		X, Units	Y, Units	1s, Units	X Samples CV%	Y Samples CV%	1s, Units	CV%	1s, Units	CV%
233-234	114	37.4	35.9	1.11	3.0	3.1	2.34	6.2	2.35	6.5
231-232	115	36.6	36.3	0.92	2.5	2.5	2.65	7.2	2.72	7.5
229-230	103	35.8	35.5	0.76	2.1	2.1	2.00	5.6	2.07	5.8
227-228	118	48.0	47.7	0.87	1.8	1.8	2.76	5.7	2.53	5.3
225-226	101	33.9	33.9	0.99	2.9	2.9	1.75	5.2	1.76	5.2
223-224	101	43.1	34.0	1.48	3.4	4.4	3.25	7.5	2.73	8.0
221-222	106	49.3	49.4	1.04	2.1	2.1	2.58	5.2	2.67	5.4
219-220	97	42.9	42.8	1.18	2.7	2.8	2.17	5.1	2.14	5.0
217-218	98	32.5	32.6	0.75	2.3	2.3	2.15	6.6	2.03	6.2
215-216	105	41.4	41.5	0.76	1.8	1.8	3.08	7.4	2.83	6.8
213-214	105	43.1	43.0	0.70	1.6	1.6	2.96	6.9	3.09	7.2
211-212	109	43.4	43.5	1.01	2.3	2.3	2.59	6.0	2.46	5.7
209-210	109	19.8	19.8	0.65	3.3	3.3	2.21	11.2	2.21	11.2
207-208	112	64.6	64.7	1.20	1.9	1.9	3.35	5.2	3.58	5.5
205-207	122	39.0	38.8	1.00	2.6	2.6	2.53	6.5	2.52	6.5
203-204	123	33.6	33.8	0.91	2.7	2.7	2.50	7.5	2.50	7.4
201-202	121	50.1	50.0	1.33	2.7	2.7	3.40	6.7	3.40	6.8
199-200	121	68.4	67.9	1.62	2.4	2.4	4.20	6.2	3.90	5.7
197-198	126	49.0	49.2	1.45	3.0	3.0	3.40	7.0	3.30	6.7
195-196	124	31.8	32.1	1.23	3.9	3.8	3.00	9.5	3.00	9.3
193-194	127	37.0	36.9	1.18	3.2	3.2	2.90	7.7	2.80	7.6

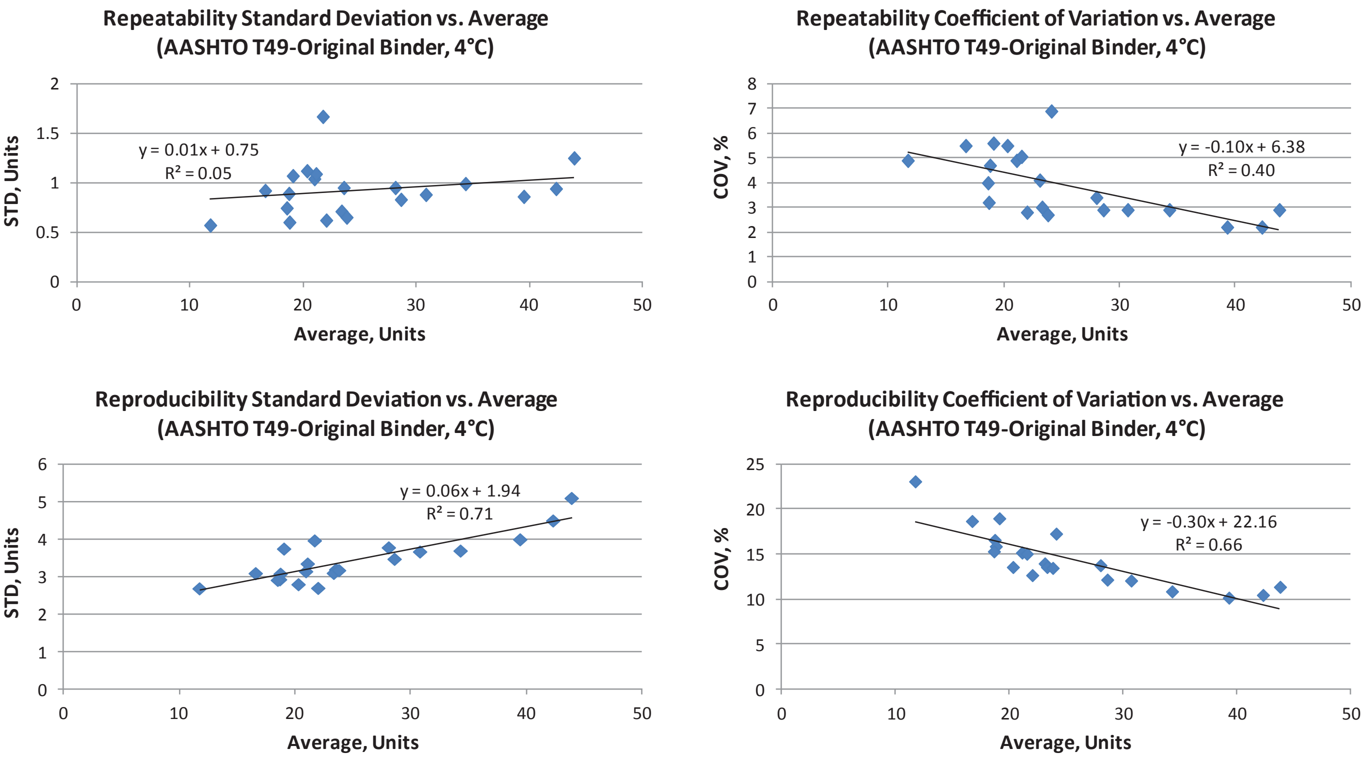

Figure 2-5 Relationship between average and standard deviation and between average and coefficient of variation for penetration (AASHTO T 49) of original asphalts at 4°C.

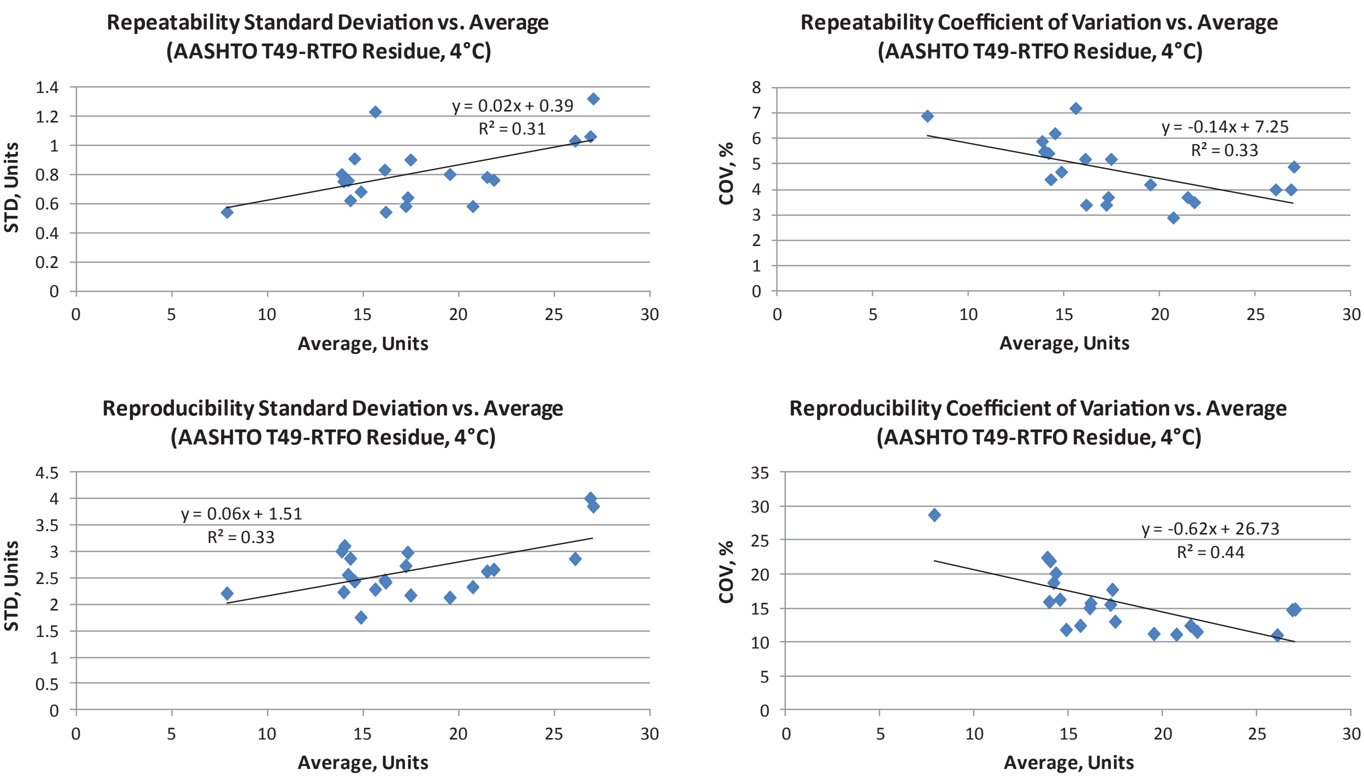

Figure 2-6 Relationship between average and standard deviation and between average and coefficient of variation for penetration (AASHTO T 49) of RTFO residue at 4°C.

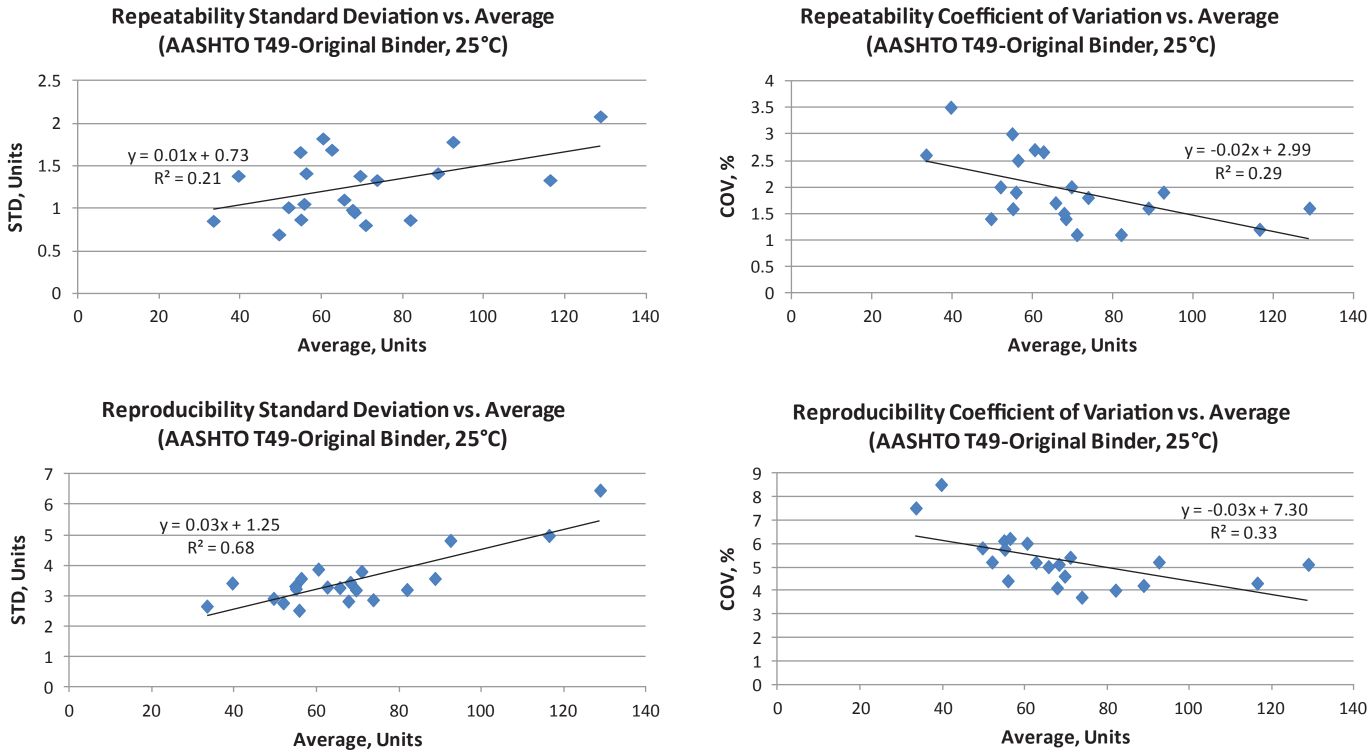

Figure 2-7 Relationship between average and standard deviation and between average and coefficient of variation for penetration (AASHTO T 49) of original asphalts at 25°C.

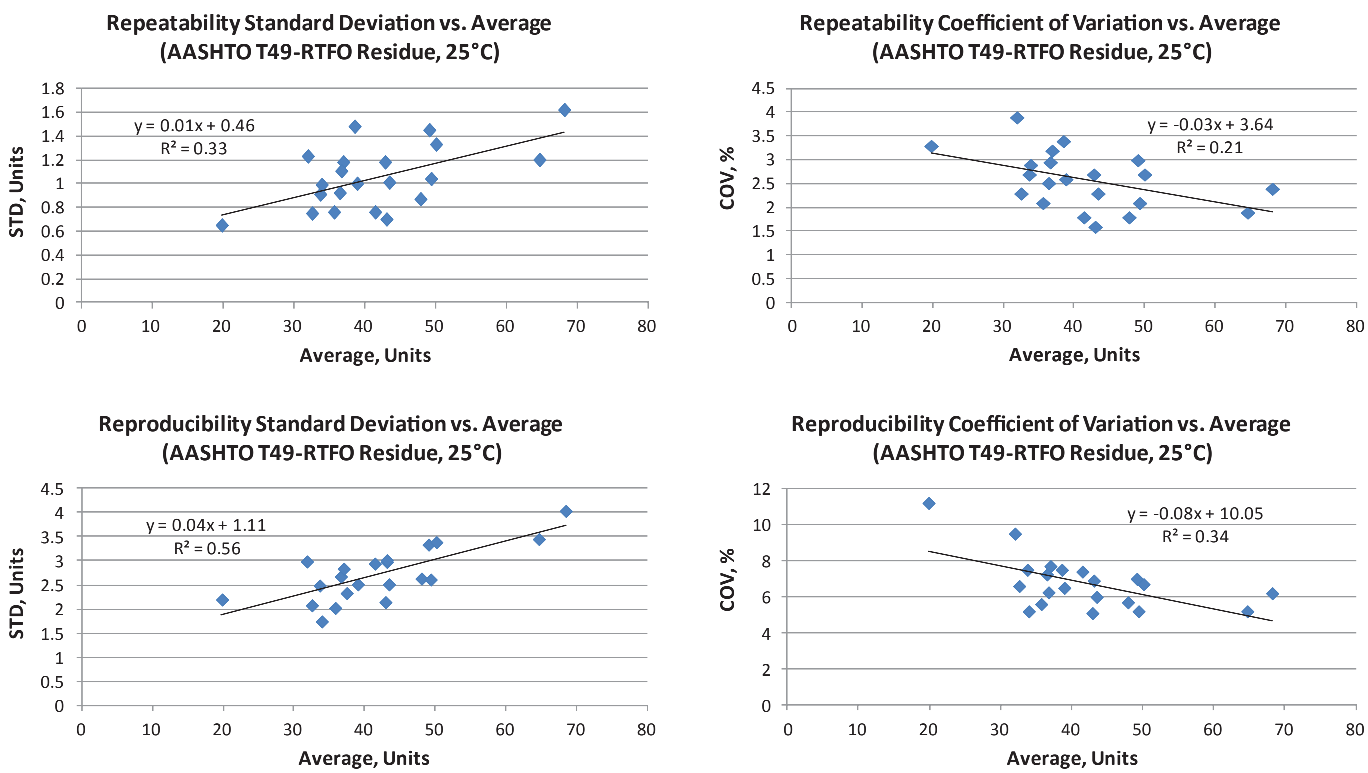

Figure 2-8 Relationship between average and standard deviation and between average and coefficient of variation for penetration (AASHTO T 49) of RTFO residue at 25°C.

Table 2-11 The new and existing repeatability and reproducibility precision equations of AASHTO T 49 based on samples' standard deviations.

Test Temperature	Material	Statistics	New 1s (units)	Existing 1s (units)
4°C	Original	Repeatability	$\sigma = 0.01X + 0.8$	$\sigma = 0.02X + 0.8$
		Reproducibility	$\sigma = 0.06X + 1.9$	$\sigma = 0.08X + 2.5$
	RTFO	Repeatability	$\sigma = 0.02X + 0.4$	$\sigma = 0.02X + 0.8$
		Reproducibility	$\sigma = 0.06X + 1.5$	$\sigma = 0.08X + 2.5$
25°C	Original	Repeatability	$\sigma = 0.01X + 0.7$	$\sigma = 0.03(X - 60) + 0.8$ when $X > 60$
		Reproducibility	$\sigma = 0.03X + 1.3$	$\sigma = 0.05(X - 60) + 2.5$ when $X > 60$
	RTFO	Repeatability	$\sigma = 0.01X + 0.5$	$\sigma = 0.8$ where $X < 60$
		Reproducibility	$\sigma = 0.04X + 1.2$	$\sigma = 2.5$ when $X < 60$

NOTE: X is the average penetration value (Units) and σ is the 1s repeatability standard deviation (Units).

precision estimate equations for the penetration values at 4°C and 25°C. For 4°C, there is one equation for each single-operator and multilaboratory precision. For 25°C, there are two equations for each single-operator and multilaboratory precision based on the penetration values below and above 60 units. The range of average penetration values is reported as 29 to 286 units.

The new single-operator and multilaboratory precision estimates are each divided into four equations corresponding to original asphalt and RTFO residue samples, each tested at 4°C and 25°C. The range of the average penetration values used for computing the new precisions are 8 to 129 units.

Table 2-11 provides the existing and the new precision equations. In the equations, σ is 1s repeatability standard deviation and X is the average value of the two test results. The maximum allowable difference between two results (d2s) in a single laboratory and between two laboratories can be determined by multiplying the standard deviation estimates provided in Table 2-11 by a factor of 2.83.

Figure 2-9 and Figure 2-10 demonstrate the existing and new single-operator and multilaboratory standard deviation equations along with the standard deviation values calculated from the PSP original asphalt and RTFO residue penetration results. In the figures, the existing equations are shown by a solid line, the new equations are shown by a dashed line, and the PSP standard deviations are shown by triangle points. The comparisons of the existing and new precision equations using Figure 2-9 and Figure 2-10 are explained in the subsequent paragraphs.

Comparison at 4°C. Figure 2-9 presents the new and existing equations for the repeatability and reproducibility standard deviations for penetration of original asphalt and RTFO residue at 4°C. The actual standard deviations computed from the PSP penetration data at 4°C are also shown in the graph. The new equations provide separate standard deviations for the original asphalt and RTFO residue; however, the existing equation does not distinguish between original asphalt and RTFO residue. As indicated, for the range of penetration values of the original asphalt (11.7 to 44.0 units) and RTFO residue (7.8 to 27.2 units), the new set of equations (dashed line) provide smaller repeatability standard deviation values than the existing equation (solid line). Similarly, the new equations for multilaboratory standard deviation provide smaller standard deviations for both original asphalt and RTFO asphalt than does the existing equation.

Comparison at 25°C. Figure 2-10 presents the equations for the repeatability and reproducibility standard deviations of penetration for the original asphalt and RTFO residue at 25°C. The actual standard deviation values computed from the PSP penetration data at 25°C are also shown in the graph. The new equations provide separate standard deviations for the original asphalt and the RTFO residue. On the other hand, the existing equations provide a separate set of standard deviations based on the level of penetration above and below 60 units, which could correspond to penetration of original asphalt and RTFO residue, respectively. As indicated from the graphs, the new repeatability equation for the

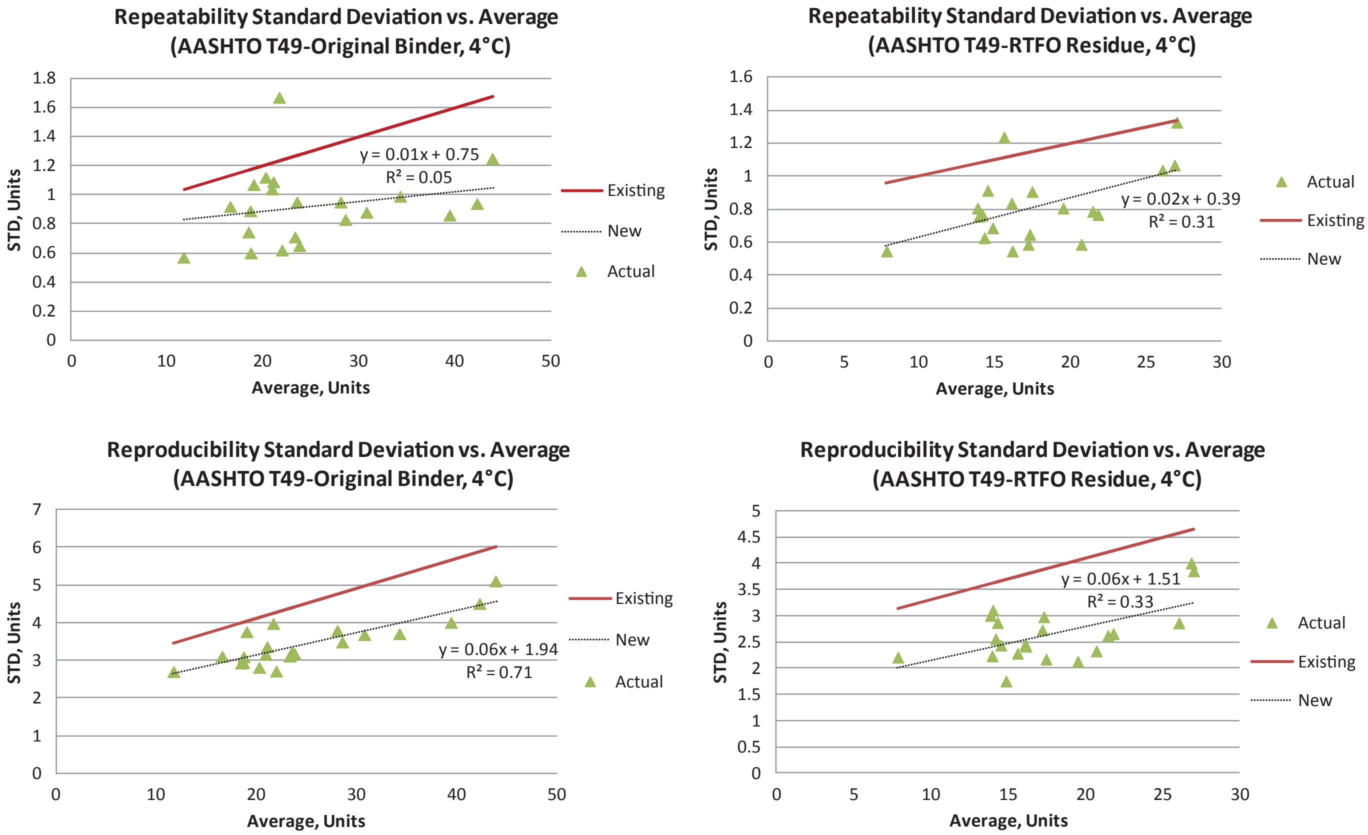

Figure 2-9 Comparison of the existing and new repeatability/reproducibility standard deviations for penetration (AASHTO T 49) of original binder and RTFO residue at 4°C.

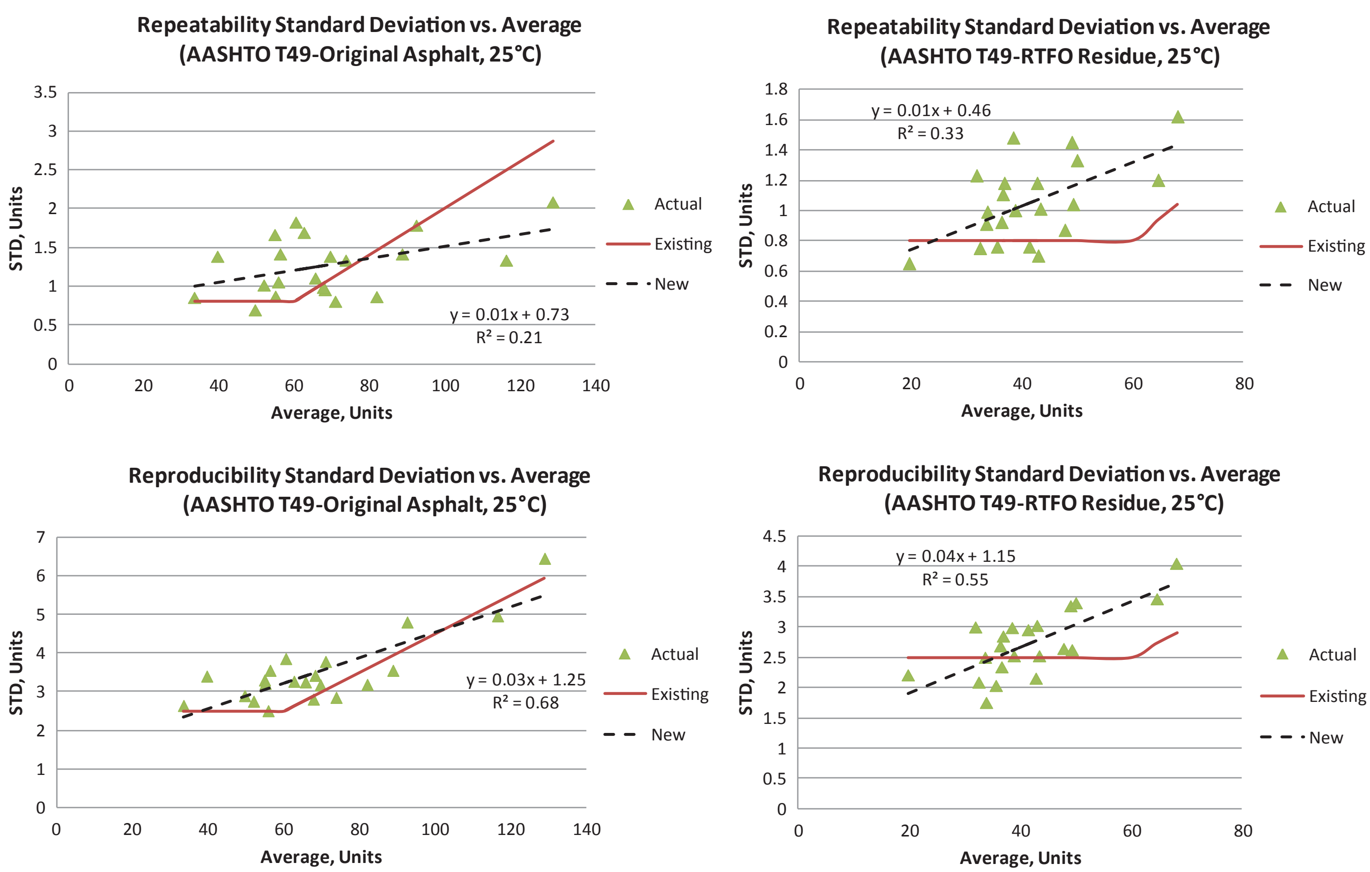

Figure 2-10 Comparison of the existing and new repeatability and reproducibility standard deviations for penetration (AASHTO T 49) of original binder and RTFO residue at 25°C.

original asphalt provides larger standard deviation values than do the existing equations for the range of penetration of 30 to 80 units. For the average penetration larger than 80 units, the new equation provides smaller standard deviations than does the existing equation. On the other hand, the new repeatability equation for the standard deviation of RTFO residue at 25°C provides larger standard deviation values than does the existing equation for a range of 30 to 70 units.

As is shown in Figure 2-10, the new equations for multilaboratory standard deviation provide larger standard deviation values than do the existing equations for the penetration range of 30 to 85 units. For the average penetration values above 85 units, the new equation provides smaller standard deviations than does the existing equation. For the reproducibility standard deviation of RTFO residue at 25°C, the new equation provides smaller standard deviation for penetration of less than 35 units and larger standard deviation values than does the existing equation for average penetration values larger than 35 units.

CHAPTER 3—CONCLUSIONS AND PROPOSED CHANGES TO STANDARD TEST METHODS

3.1 Conclusions

This study was conducted under Task 2 of NCHRP Project 10-87 to update precision estimates of three AASHTO test methods pertaining to asphalt binder: T 201, "Kinematic Viscosity of Asphalts (Bitumens)," T 202, "Viscosity of Asphalts by Vacuum Capillary Viscometer," and T 49, "Penetration of Bituminous Materials." AMRL PSP data were used to compute the estimates of precision. The data collected include the test properties of both original asphalt and RTFO residue of the 21 most recent pairs of PSP VGAC samples tested according to AASHTO T 201, T 202, and T 49. The study conclusions and proposals are detailed in the following sections.

3.1.1 AASHTO T 201

For AASHTO T 201-10, which is identical to ASTM D 2170-10, the new set of precision estimates includes separate coefficients of variation for the kinematic viscosity of the original and RTFO asphalt binders. The existing precision statement provides a single set of coefficients of variation for asphalt cement, which are significantly smaller than the new set of coefficients of variation. The existing single-operator repeatability precision for kinematic viscosity of asphalt at 135°C is 0.64%, while the new precisions corresponding to original asphalt and RTFO residue are 1.3% and 1.7%, respectively.

The existing multilaboratory coefficient of variation for kinematic viscosity of asphalt cement at 135°C is 3.1%; however, the new multilaboratory coefficient of variation for the original asphalt is 2.3% and for the RTFO residue is 3.6%. The average of the new multilaboratory coefficients of variation from the original asphalt and RTFO residue are equivalent to the existing multilaboratory coefficient of variation.

The differences between the new and existing repeatability precisions may arise from analyzing a wider range of kinematic viscosity values for the new precisions than those used for the existing precisions. Moreover, the difference between the new and existing reproducibility precisions may arise from separating the precisions for the original asphalt and RTFO residue. The variability of the kinematic viscosity of the RTFO residue is expected to be larger than that of original asphalt since the variability of the RTFO aging (AASHTO T 240) is also included in the variability of the viscosity measurements.

3.1.2 AASHTO T 202

For AASHTO T 202-10, which is identical to ASTM D 2171-10, the new set of precisions includes separate coefficients of variation for the viscosity by capillary vacuum of the original asphalt and RTFO residue tested at 60°C. The existing precision statement provides a single set of precisions for asphalt cement tested at 60°C, which are significantly different from the new set of precisions.

The existing allowable difference between two replicate results is 7% of the mean; however, the new allowable difference between two replicate results is 4.1% of the mean for the original binder and 7.6% of the mean for the RTFO residue.

The existing allowable difference between the results of two laboratories is 10% of the mean.

However, the new precision estimates, separated between the viscosity of original asphalt and the RTFO residue, set the allowable difference between two laboratories' results as 8.8% of the mean for the original asphalt and 19.7% of the mean for the RTFO residue.

The differences in the new and existing precisions may arise from using a wider range of asphalt binders for preparing the new precision estimates than those used for preparing the existing precisions, although this cannot be confirmed. The difference could also be due to separating the precisions for the original asphalt and RTFO residue, resulting in smaller precision estimates than the existing one for the original asphalt and larger precision estimates than the existing for the RTFO residue. This is expected because, for the RTFO residue, the variability of RTFO aging would be included in the variability of viscosity measurements.

3.1.3 AASHTO T 49

AASHTO T 49-07 is identical to ASTM D 5-06 except for several provisions described in AASHTO T 49-07. The existing precision statement in ASTM D5-06 includes six single-operator and multilaboratory precision estimate equations for the penetration values at 4°C and 25°C. For 4°C, there is one equation for each single-operator and multilaboratory precision. For 25°C, there are two equations for each single-operator and multilaboratory precision based on the penetration values below and above 60 units. The range of average penetration values is reported as 29 to 286 units.

The new precision estimate breaks each single-operator and multilaboratory precision estimate into four equations based on the results from the original and the RTFO binder samples tested at 4°C and 25°C. The new precisions cover a range of penetration values from 8 to 129 units.

3.1.3.1 Comparison at 4°C. The comparison of existing and new precision estimate values indicated that at 4°C, the new set of equations provide smaller repeatability standard deviation values than the existing equation. Similarly, the new equations for multilaboratory standard deviation provide smaller standard deviations for both original asphalt and RTFO residue than does the existing equation (see Figure 2-9).

3.1.3.2 Comparison at 25°C. At 25°C, the new repeatability equation for the original asphalt provides larger standard deviation values than do the existing equations for penetration less than 80 units and smaller standard deviation values than do the existing equations for penetration larger than 80 units. The new repeatability equation for the standard deviation of RTFO residue at 25°C provides larger standard deviation values than does the existing equation for penetration values above 25 units (see Figure 2-10).

The new equations for multilaboratory standard deviation at 25°C provide larger standard deviation values than do the existing equations for the penetration values larger than 30 and smaller than 100 units. For the penetration values larger than 100 units, the new equation provides a smaller standard deviation than does the existing equation. For the RTFO residue at 25°C, the new equation provides a smaller standard deviation for a penetration less than 35 units and larger standard deviation values than does the existing equation for a penetration above 35 units (see Figure 2-10).

The observed differences between the new and existing precisions may arise from (1) testing asphalt binders with a different range of penetration values collected most recently as part of the AMRL PSP; (2) separating the precision estimates of the original asphalt and RTFO residue; (3) using the new AMRL statistical analysis method, which began in 2004, while the existing precision estimates were developed based on an older analysis method; and (4) any improvements to the test method that would not be reflected in the results collected at the time when the existing precisions were developed.

3.2 Proposed Changes to AASHTO Standard Test Methods T 201, T 202, and T 49

The following changes are proposed on the basis of the differences observed between the existing precision estimates and those developed in this study.

3.2.1 AASHTO T 201

It is proposed that the precision and bias statement in Appendix F be adopted for AASHTO T 201. This is in consideration of the differences between the current precision estimates in ASTM D 2170 and those developed in this study.

3.2.2 AASHTO T 202

It is proposed that the precision and bias statement in Appendix G be adopted for AASHTO T 202. This is in consideration of the differences between the current repeatability and reproducibility precision estimates in ASTM D 2171 and those developed in this study.

3.2.3 AASHTO T 49

It is proposed that the precision and bias statement in Appendix H be adopted for AASHTO T 49. This is in consideration of the differences between the repeatability and reproducibility precision estimates of the current ASTM D5-06 and those developed in this study.

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UNPUBLISHED APPENDIXES

The following appendixes are not published herein, but can be found online at http://www.trb.org by searching for NCHRP Project 10-87. The appendixes are titled as follows:

Appendix A—New Analysis Method for Preparing Precision Estimates Using Proficiency Data
Appendix B—Proficiency Sample Instructions and Data Sheets
Appendix C—Graphs of T 201 Proficiency Sample Data
Appendix D—Graphs of T 202 Proficiency Sample Data
Appendix E—Graphs of T 49 Proficiency Sample Data

APPENDIX F—PRECISION STATEMENT FOR AASHTO T 201

Kinematic Viscosity of Asphalts (Bitumens)

X. Precision and Bias

X.1. Precision. Criteria for judging the acceptability of kinematic viscosity of asphalt are given in Table X.

NOTE—The figures given 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 in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

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.

Table X Precision estimates of kinematic viscosity of asphalts (bitumens).

Condition of Test and Test Property	Coefficient of Variation (percent of mean) 1s%[a]	Acceptable Range of Two Test Results (percent of mean) d2s%[a]
Single-operator precision:		
Original	1.3	3.8
RTFO (average of kinematic viscosity < 850 mm^2/s)	1.5	4.2
RTFO (average of kinematic viscosity ≥ 850 mm^2/s)	2.7	7.6
Multilaboratory precision:		
Original	2.3	6.6
RTFO (average of kinematic viscosity < 850 mm^2/s)	3.3	9.2
RTFO (average of kinematic viscosity ≥ 850 mm^2/s)	5.1	14.4

[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 test results from 21 pairs of AMRL VGAC proficiency samples. The data analyzed consisted of results from 75 to 118 laboratories for each of the pairs of samples. The analysis included asphalt cements with the average kinematic viscosity of 283 mm^2/s to 702 mm^2/s for the original asphalt and 429 mm^2/s to 1,036 mm^2/s for the RTFO residue.

APPENDIX G—PRECISION STATEMENT FOR AASHTO T 202

Viscosity of Asphalts by Vacuum Capillary Viscometer

X. Precision and Bias

X.1. Precision. Criteria for judging the acceptability of kinematic viscosity of asphalt are given in Table X.

NOTE—The figures given 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 in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

Table X Precision estimates of viscosity of asphalts by vacuum capillary viscometer.

Condition of Test and Test Property	Coefficient of Variation (percent of mean) 1s%[a]	Acceptable Range of Two Test Results (percent of mean) d2s%[a]
Single-operator precision:		
Original	1.5	4.2
RTFO	2.7	7.7
Multilaboratory precision:		
Original	3.1	8.8
RTFO	6.8	19.2

[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 test results from 21 pairs of AMRL VGAC proficiency samples. The data analyzed consisted of results from 94 to 135 laboratories for each of the pairs of samples. The analysis included asphalt cements with the average viscosity by vacuum capillary in a range of 102 Pa.s to 5,930 Pa.s for the original asphalt and 403 Pa.s to 11,585 Pa.s for the RTFO residue.

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.

APPENDIX H—PRECISION STATEMENT FOR AASHTO T 49

Penetration of Bituminous Materials

X. Precision and Bias

X.1. Precision. Criteria for judging the acceptability of Penetration of Bituminous Materials are given in Table X.

NOTE—The figures given in Column 2 are the standard deviations that have been found to be appropriate for the materials and conditions of test described in Column 1. The figures in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

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.

Table X Precision estimates of penetration of bituminous materials.

Condition of Test and Test Property		Standard Deviation 1s[a,b]	Acceptable Range of Two Test Results d2s[a,b]
Single-operator precision:			
4°C	Original	1s = 0.01X + 0.8	1s = (0.01X + 0.8) × 2.83
	RTFO	1s = 0.02X + 0.4	1s = (0.03X + 0.3) × 2.83
25°C	Original	1s = 0.01X + 0.7	1s = (0.01X + 0.6) × 2.83
	RTFO	1s = 0.01X + 0.5	1s = (0.02X + 0.5) × 2.83
Multilaboratory precision:			
4°C	Original	1s = 0.06X + 1.9	1s = (0.06X + 2.0) × 2.83
	RTFO	1s = 0.06X + 1.5	1s = (0.07X + 1.5) × 2.83
25°C	Original	1s = 0.03X + 1.3	1s = (0.02X + 1.8) × 2.83
	RTFO	1s = 0.04X + 1.2	1s = (0.04X + 1.2) × 2.83

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

[b]The value of X represents the average value of two test results.

NOTE: The precision estimates given in Table X are based on the analysis of test results from 21 pairs of AMRL VGAC proficiency samples. The data analyzed consisted of results from 71 to 97 laboratories for each of the pairs of samples. The analysis included original asphalt cements with the average penetration value of 11.7 units to 44 units at 4°C and 33.4 units to 128.9 units at 25°C and RTFO residue with the average penetration value of 7.8 units to 27.2 units at 4°C and 19.8 units to 68.4 units at 25°C.

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500 Fifth Street, NW
Washington, DC 20001

ISBN 978-0-309-28394-6

Subscriber Categories: Materials

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