
Research Results Digest 351

Precision Statements for AASHTO Standard Methods of Test T 148, T 265, T 267, AND T 283

DETAILS

9 pages | | PAPERBACK
ISBN 978-0-309-15526-7 | DOI 10.17226/14481

AUTHORS

January 2011

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Responsible Senior Program Officer: E. T. Harrigan

Research Results Digest 351

PRECISION STATEMENTS FOR AASHTO STANDARD METHODS OF TEST T 148, T 265, T 267, AND T 283

This digest summarizes key findings obtained in 2009 and 2010 from continuing NCHRP Project 9-26A, "Data Mining and Interlaboratory Studies to Prepare Precision Statements for AASHTO Standard Test Methods." Project 9-26A was conducted by the AASHTO Materials Reference Laboratory under the direction of the principal investigator, Haleh Azari. This digest is based on the contractor's task reports, which are available online as *NCHRP Web-Only Documents 163* through *166*.

INTRODUCTION

The objective of NCHRP Project 9-26A was to develop or update precision statements of AASHTO standard methods of test designated by the technical sections of the AASHTO Highway Subcommittee on Materials (HSOM). To meet this objective, NCHRP Project 9-26A used both data mining techniques and interlaboratory studies (or "round robins," as defined in ASTM D6631, Standard Guide for Committee D01 for Conducting an Interlaboratory Practice for the Purpose of Determining the Precision of a Test Method).

This research results digest summarizes the findings of four interlaboratory studies (ILS) conducted in 2009 and 2010 to develop precision statements for the AASHTO standard methods of test shown in Table 1. Reports were published in the form of NCHRP *web-only documents* (WODs) as tasks related to individual standard methods were completed. Precision statements and supporting results were provided to the AASHTO HSOM for review and possible adoption.

A complete report of the development of each precision statement is presented in the four WODs (*1, 2, 3, 4*) shown in Table 1.

FINDINGS

AASHTO T 148, "Measuring Length of Drilled Concrete Cores"

An ILS was conducted to prepare precision estimates for AASHTO T 148, "Measuring Length of Drilled Concrete Cores." Six drilled concrete cores with varying dimensions and surface roughness were obtained from several test sections in the FHWA's Long-Term Pavement Performance program. The cores were delivered to 11 laboratories, where the length of each core was measured using a 3-point caliper described in AASHTO T 148. The measurements were carried out at nine different locations at the center and along the circumference of the cores. A complete set of measurements was repeated five times by each laboratory for the purpose of determining repeatability precision estimates. The collected data were analyzed according to ASTM E691, "Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method." Table 2 summarizes the test data from the participating laboratories and their statistical analysis.

Analysis of the experimental data provided the following findings:

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Table 1 Test methods and web-only documents

AASHTO Standard Method of Test	NCHRP Web-Only Document
T 148, Measuring Length of Drilled Concrete Cores	*165*
T 265, Laboratory Determination of Moisture Content of Soils	*164*
T 267, Determination of Organic Content in Soils by Loss on Ignition	*163*
T 283, Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage	*166*

1. The variability of the measurements significantly increases as the length of the cores reaches the limits of the 3-point caliper measuring range described in AASHTO T 148. This was indicated by the highest repeatability standard deviation of the 12-in.-long core and highest reproducibility standard deviation of the 4-in.-long core.
2. The repeatability standard deviation increases with the increase in surface roughness of the cores as was indicated by higher variability of one of the 4-in.-diameter cores that had more surface irregularities than the other 4 in.-diameter cores. However, the variability was not statistically significant and the within-laboratory variability of all 4-in. diameter cores could be combined.
3. The variability of the measurements was found to be the same for cores with the same diameter (4-in. or 6-in.) and significantly different for cores with different diameters (4-in. and 6-in.). Therefore, the standard deviations of the measurements of the same diameter cores were combined to prepare separate sets of precisions for 4-in.- and 6-in.-diameter cores.

Precision estimates for the length measurements of the 4-in.- and 6-in.-diameter cores were computed after combining the standard deviations that were not significantly different. Based on the significant difference in the precision estimates of 4-in.- and 6-in.-diameter cores, repeatability and reproducibility precision estimates were reported separately for each diameter. The resulting standard deviations and the allowable range of differences between two results within one laboratory and between different laboratories are presented in Table 3.

AASHTO T 265, "Laboratory Determination of Moisture Content of Soils"

An ILS was conducted to prepare precision estimates for AASHTO T 265, "Laboratory Determination of Moisture Content of Soils." Test data were collected for four aggregate-soil blends judged suitable for base and subbase construction. Specifi-

Table 2 Summary of statistics of concrete core length measurements (mm)

Sample ID	# of Labs	D x L (inches)	Intended Height (mm)	Average Measured Height (mm)	STD S_x (mm)	CV%	Repeatability (S_r)		Reproducibility (S_R)	
							1s, (mm)	CV%	1s, (mm)	CV%
LT 659	9	6 x 12	304.80	314.47	2.40	0.76	0.29	0.09	2.41	0.77
LT 755	10	6 x 8	203.20	203.55	1.70	0.83	0.60	0.29	1.78	0.87
LT 425	10	6 x 6	152.40	152.48	1.58	1.03	0.76	0.50	1.72	1.13
LT 2894	8	4 x 9	228.60	228.23	0.43	0.19	0.28	0.12	0.50	0.22
LT 1119	8	4 x 7	177.80	177.22	1.01	0.57	0.49	0.28	1.10	0.62
LT 523	8	4 x 4	101.60	107.36	2.24	2.09	0.31	0.29	2.26	2.10

*D and L stand for diameter and length, respectively, of the cores.

Table 3 Precision estimates for measurement of drilled concrete cores based on AASHTO T 148

Condition of Test and Test Property	Standard Deviation, mm	Acceptable Range of Two Results, mm
Repeatability (S_r)		
4-in.-diameter	0.4	1.0
6-in.-diameter	0.7	1.9
Reproducibility (S_R)		
4-in.-diameter	0.9	2.4
6-in.-diameter	1.8	4.9

cally, there were two coarse-graded blends—one containing clay filler (Blend CC) and the other silt filler (Blend CS), and two fine-graded blends—one containing clay filler (Blend FC) and the other silt filler (Blend FS). Blends with a limited amount of materials passing the #200 sieve were selected.

The ILS samples were prepared at the AASHTO Materials Resources Laboratory (AMRL) Proficiency Sample Facility using procedures developed for the AMRL Proficiency Sample Program. A total of 1,260 samples were prepared and sent to the 35 selected laboratories. Each laboratory received 36 samples that consisted of three replicates of each of the four soil-aggregate blends prepared at three different percentages of moisture. The coarse blend samples weighed about 350 g and the fine blends samples weighed about 150 g. The fine blend samples were prepared with 4%, 6%, and 8% moisture (designated as *below optimum, optimum,* and *above optimum,* respectively); the coarse blend samples were prepared with 3 %, 5 %, and 7% moisture (designated *below optimum, optimum,* and *above optimum,* respectively).

The experimental data were analyzed according to ASTM E691, "Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method." Tables 4 through 7 summarize the test data from the participating laboratories and their statistical analysis for the four blends.

Analysis of the data provided the following findings:

1. The standard deviations of the blends with clay were not significantly different from those of the blends with silt. Therefore, the standard deviations were combined.
2. The standard deviations of the coarse blends with 3% moisture (below optimum) were not significantly different from those of the blends with 5% moisture (optimum). Therefore, these standard deviations were combined.
3. The standard deviations of the coarse blends with 7% moisture (above optimum) were significantly different from those of the blends with 3% and 5% moisture content. Due to uncertainty in the results of 7% moisture content, they were not included in the precision estimate analysis.

Table 4 Summary of statistics of % moisture content of coarse aggregate with clay (CC)

Sample Type	# of Labs	Target %	Average %	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
						1s, %	d2s, %	1s, %	d2s, %
Coarse Aggregate w/ clay (3% moisture)	27	3.0	3.02	0.06	1.9	0.042	0.1	0.07	0.2
Coarse Aggregate w/ clay (5% moisture)	28	5.0	4.98	0.11	2.3	0.044	0.1	0.12	0.3
Coarse Aggregate w/ clay (7% moisture)	25	7.0	6.89	0.26	3.8	0.060	0.2	0.27	0.8

Table 5 Summary of statistics of % moisture content of coarse blend with silt (CS)

Sample Type	# of Labs	Target %	Average %	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
						1s, %	d2s, %	1s, %	d2s, %
Coarse aggregate w/ silt (3% moisture)	27	3.0	3.03	0.05	1.6	0.05	0.1	0.06	0.2
Coarse aggregate w/ silt (5% moisture)	29	5.0	5.02	0.10	2.1	0.06	0.2	0.12	0.3
Coarse aggregate w/ silt (7% moisture)	29	6.6	6.60	0.33	5.0	0.44	1.2	0.49	1.4

Table 6 Summary of statistics of % moisture content of fine blend with clay (FC)

Sample Type	# of Labs	Target %	Average %	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
						1s, %	d2s, %	1s, %	d2s, %
Fine Aggregate w/ clay (4% moisture)	30	4.0	4.04	0.14	3.4	0.18	0.5	0.20	0.6
Fine Aggregate w/ clay (6% moisture)	29	6.0	5.92	0.20	3.4	0.17	0.5	0.25	0.7
Fine Aggregate w/ clay (8% moisture)	30	8.0	7.39	0.63	8.5	0.73	2.0	0.87	2.4

Table 7 Summary of statistics of % moisture content of fine blend with silt (FS)

Sample Type	# of Labs	Target %	Average %	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
						1s, %	d2s, %	1s, %	d2s, %
Fine Aggregate w/ silt (4% moisture)	29	4.0	3.97	0.11	2.9	0.17	0.5	0.18	0.5
Fine Aggregate w/ silt (6% moisture)	30	6.0	5.97	0.16	2.7	0.12	0.3	0.19	0.5
Fine Aggregate w/ silt (8% moisture)	30	8.0	7.69	0.46	6.0	0.60	1.7	0.68	1.9

4. The standard deviations of the fine blends with 4% moisture content (below optimum) and those of the blends with 6% moisture content (optimum) were not significantly different. Therefore, these standard deviations were combined.
5. The standard deviations of the fine blends with 8% moisture content (above optimum) were significantly different from those of the blends with 4% and 6% moisture content. Due to uncertainty in the results of 8% moisture content, they were not included in the precision estimate analysis.
6. The bias and low precision of the moisture content data for the above optimum blends were speculated to be due to availability of excess moisture for evaporation. When the mixture is above the optimum moisture content, free moisture is available to evaporate and escape from the pores of the bottles. However, in mixtures below the optimum and at the optimum, moisture adheres to the soil-aggregate particles.
7. The standard deviations of the coarse blends were significantly different from those of fine blends. Therefore the computed precision estimates from the two blends are presented separately in the proposed precision statement.

Table 8 presents the precision estimates for moisture content determination based on the results of the

Table 8 Combined standard deviations of the blends with various moisture contents

Material and Type Index	Standard Deviations (1s)	Acceptable Range of Two Results (d2s)
Single-Operator Precision:		
Coarse blend	0.05	0.14
Fine blend	0.16	0.46
Multilaboratory Precision:		
Coarse blend	0.12	0.33
Fine blend	0.21	0.58

ILS conducted in this study. The standard deviations corresponding to coarse and fine blends were used to compute the allowable differences between two moisture content measurements.

AASHTO T 267, "Determination of Organic Content in Soils by Loss on Ignition"

An interlaboratory study was conducted to prepare precision estimates for AASHTO T 267, Determination of Organic Content in Soils by Loss on Ignition." Samples from three types of soils (clay, silt, and sand) were each blended with three different percentages (2%, 5%, and 8%) of fine walnut shell grits as organic material and sent to 30 laboratories for organic content measurement. The laboratories were instructed to test three replicates of each organic content level of each soil type. Results were obtained from 27 different laboratories.

ILS test results were analyzed for precision in accordance to ASTM E 691. Before the analysis, any outlier data were eliminated by following the procedures described in ASTM E 691 for determining repeatability (S_r) and reproducibility (S_R) estimates of precision. For each set of data, the *h* and *k* statistics, representing the between and within laboratory consistency, were used to identify the outlier data. Data exceeding the critical *h* and *k* values were eliminated; once identified for elimination, the same data were eliminated from any smaller subsets analyzed.

Multiple sets of data in each soil type were eliminated based on the critical *h* and *k* values. After eliminating the outlier data, the averages and the repeatability and reproducibility standard deviations of the data were determined. The S_r and S_R precision estimates were determined using the remaining data in conformance with ASTM E 691.

A summary of statistics of the measurements is shown in Table 9. The comparison of the design and measured organic content values in the table indicates that every soil has a certain percentage of intrinsic organic material; clay has the greatest amount of intrinsic organic material, whereas sand has the least amount. Upon subtracting the intrinsic organic contents from the measured organic contents, the average of the measured values agree closely with the design values as shown in Table 10.

In addition to the adjusted averages, Table 10 also provides the adjusted variability of the measurements. The table shows that the standard deviation of the measurements for sand increases with the increase in the percentage of organic material. The increased variability of the sand blend with higher percentages of organic material indicates segregation of organic material during shipment. This could be explained by the non-cohesive nature of sand that does not allow the ground walnut shell grits to adhere to sand particles.

Analysis of the data provided the following findings:

1. Clay has the greatest amount of intrinsic organic material and sand has the least amount.
2. The within-laboratory and between-laboratory standard deviations were very consistent for different organic content levels of clay or silt blend. Therefore, for these two blends, the standard deviations corresponding to 2%, 5%, and 8% organic material were combined.
3. For the sand blend, the within-laboratory and between-laboratory standard deviations of

Table 9 Summary of statistics of organic content measurements after elimination of outlier data

Soil Type	Design Organic Content	No. of Labs	Average Measured Organic Content	S_x	Repeatability		Reproducibility	
					1s (S_r)	d2s	1s (S_R)	d2s
Clay	0%	27	3.03	0.981	0.277	0.785	1.018	2.880
Clay	2%	25	5.38	0.925	0.287	0.813	0.966	2.735
Clay	5%	26	8.29	0.985	0.259	0.732	1.017	2.879
Clay	8%	24	11.16	0.787	0.233	0.661	0.819	2.319
Silt	0%	26	0.95	0.369	0.122	0.346	0.388	1.098
Silt	2%	25	6.06	0.378	0.129	0.366	0.544	1.540
Silt	5%	25	2.92	0.529	0.155	0.437	0.408	1.154
Silt	8%	25	8.93	0.379	0.195	0.551	0.424	1.199
Sand	0%	25	0.32	0.140	0.052	0.147	0.149	0.422
Sand	2%	26	5.55	0.362	0.219	0.621	0.363	1.027
Sand	5%	25	2.43	0.292	0.430	1.216	0.555	1.570
Sand	8%	26	8.59	0.631	0.396	1.120	0.741	2.097

Table 10 Summary of statistics of organic content measurements after subtracting the intrinsic organic content

Soil Type	Source-Design	No. of Labs	Average	S_x	Repeatability		Reproducibility	
					1s (S_r)	d2s	1s (S_R)	d2s
Adj. Clay	2%	26	2.25	0.505	0.282	0.798	0.576	1.630
Adj. Clay	5%	25	5.32	0.498	0.246	0.697	0.554	1.567
Adj. Clay	8%	24	8.28	0.519	0.232	0.655	0.566	1.602
Adj. Silt	2%	25	1.97	0.313	0.129	0.366	0.338	0.956
Adj. Silt	5%	25	5.05	0.262	0.155	0.437	0.302	0.856
Adj. Silt	8%	26	7.93	0.368	0.196	0.556	0.415	1.176
Adj. Sand	2%	25	2.07	0.262	0.216	0.610	0.337	0.953
Adj. Sand	5%	25	5.14	0.534	0.397	1.124	0.660	1.869
Adj. Sand	8%	25	8.24	0.683	0.372	1.054	0.774	2.192

Table 11 Precision estimates for measurement of organic content of soil

Condition of Test and Test Property	Standard Deviation, % (1s)	Acceptable Range of Two Results, % (d2s)
Single-Operator Precision:		
Clay	0.25	0.72
Silt and Sand	0.19	0.54
Multilaboratory Precision:		
Clay	0.57	1.60
Silt and Sand	0.35	1.00

5% and 8% organic content were significantly larger than those of 2% organic content. Therefore, the standard deviations corresponding to different organic content levels were not combined.

4. The large variability in measurement of organic content of sand blends with 5% and 8% organic material is speculated to be caused by segregation of organic material during shipment as a result of the non-adhesive nature of sand.
5. Since sand has typically less than 2% organic material in its natural state, the precision estimates for sand were prepared based on the standard deviations of the blend with 2% organic content and the standard deviations corresponding to 5% and 8% organic content were not included in precision estimate development.
6. The within-laboratory and between-laboratory standard deviations of the silt and sand blends were statistically similar and they were combined.
7. The within-laboratory and between-laboratory standard deviations of the clay blend were significantly different from those of sand and silt blends and were reported separately.

Table 11 presents single operator and multilaboratory estimates of variability (1s) and the allowable difference between two results (d2s) for organic content measurements of the soil blends.

AASHTO T 283, "Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage"

An interlaboratory study was conducted to prepare precision estimates for AASHTO T 283, "Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage." Two different sources of aggregates—limestone and sandstone—with varying levels of moisture resistivity and two methods of compaction—gyratory and Marshall—were selected for the study. The combination of aggregate types and compaction methods resulted in four sets of specimens to be evaluated in the study. Before conducting the ILS, the FHWA conducted a preliminary study in which the moisture susceptibly of the four selected specimen types was evaluated using AASHTO T 283 test methods and Hamburg wheel track testing. A total of 40 laboratories participated in the ILS and provided complete sets of data from testing either gyratory, Marshall, or both specimen types.

Detailed volumetric and mechanical data were collected from the laboratories in the ILS. In addition to tensile strength ratios (TSR), laboratories provided the individual indirect tensile strength values of the dry and conditioned specimens. Tables 12 through 15 summarize the test data from the participating laboratories and their statistical analysis for the four blends.

These results and those of the preliminary FHWA study indicated that AASHTO T 283 is, in general, very variable and may provide erroneous results. The limestone mixture, which was known to be highly moisture resistant, was indicated as moderately resistant to moisture while the sandstone, which was known to be moisture sensitive, showed relatively good moisture resistance. Moreover, the results demonstrated that while the repeatability standard deviations of dry and wet strength measurements and their corresponding TSR values were very similar, the reproducibility standard deviations of the reported strength measurements were significantly larger than those of their corresponding TSR values. Therefore, as suggested by a number of highway agencies, while the wet strength values can be used

Table 12 Statistics of dry and wet indirect tensile strength and TSRs of gyratory compacted limestone mixtures

Property	# of Labs	Average	Repeatability		Reproducibility	
			STD	CV%	STD	CV%
Dry Tensile Strength, kPa	18	647	28.64	4.4	135.97	21.0
Wet Tensile Strength, kPa	18	616	24.08	3.9	108.43	17.6
TSR	19	0.95	0.030	3.1	0.091	9.6

Table 13 Statistics of dry and wet indirect tensile strength and indirect TSRs of Marshall compacted limestone specimens

Property	# of Labs	Average	Repeatability		Reproducibility	
			STD	CV%	STD	CV%
Dry Tensile Strength, kPa	14	970	57.74	6.0	163.79	16.9
Wet Tensile Strength, kPa	14	852	56.76	6.7	182.56	21.4
TSR	13	0.87	0.035	4.1	0.082	9.4

Table 14 Statistics of dry and wet indirect tensile strength and indirect TSRs of gyratory compacted sandstone mixtures

Property	# of Labs	Average	Repeatability		Reproducibility	
			STD	CV%	STD	CV%
Dry Tensile Strength, kPa	21	956	49.99	5.2	286.87	30.0
Wet Tensile Strength, kPa	19	785	36.08	4.6	158.67	20.2
TSR	19	0.89	0.031	3.5	0.088	9.9

Table 15 Statistics of dry and wet indirect tensile strength and indirect TSR of Marshall compacted sandstone specimens

Property	# of Labs	Average	Repeatability		Reproducibility	
			STD	CV%	STD	CV%
Dry Tensile Strength, kPa	15	1205	67.01	5.6	381.35	32.2
Wet Tensile Strength, kPa	15	1013	55.11	5.4	332.43	35.2
TSR	16	0.88	0.035	4.0	0.087	10.6

in place of TSR for comparison of moisture susceptibility of various mixtures within one laboratory, their use for between-laboratory comparison is not advisable.

The ILS test results were analyzed for precision in accordance with ASTM E 691. Before the analysis, any partial sets of data were eliminated by following the procedures described in ASTM E 691 in determining repeatability (S_r) and reproducibility (S_R) estimates of precision. Data exceeding the critical *h* and *k* statistics, which represent the within and between variability, were eliminated. Once identified for elimination, the same data were eliminated from any smaller subsets analyzed.

The precision estimates of AASHTO T 283 are presented in Table 16. Statistical comparisons showed that the repeatability and reproducibility of TSR values of gyratory and Marshall specimens of the limestone and sandstone mixtures were not significantly different. Therefore, the repeatability and reproducibility statistics for AASHTO T 283 were determined by combining all appropriate within- and between-laboratory standard deviations. As indicated by Table 16, the acceptable range of TSR values

Table 16 Precision estimates of TSR

Condition of Test and Test Property	Standard Deviation 1s	Acceptable Range of Two Results d2s
Single-Operator Precision	0.033	0.093
Multilaboratory Precision	0.087	0.247

within one laboratory is about 9% and the acceptable range of TSR values between two laboratories is about 25%. These values validate the concerns of the highway agencies about the variability of this test method. Chapter 4 of *NCHRP Web-Only Document 166* (*4*) presents the results of an investigation of the possible causes of this high variability.

REFERENCES

1. Azari, H. *NCHRP Web-Only Document 163: Precision Estimates of AASHTO T 267: Determination of Organic Content in Soils by Loss on Ignition.* TRB, The National Academies, Washington, DC, 2010. (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w163.pdf)
2. Azari, H. *NCHRP Web-Only Document 164: Precision Estimates of AASHTO T 265: Laboratory Determination of Moisture Content of Soils.* TRB, The National Academies, Washington, DC, 2010. (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w164.pdf)
3. Azari, H. *NCHRP Web-Only Document 165: Precision Estimates of AASHTO T 148: Measuring Length of Drilled Concrete Cores.* TRB, The National Academies, Washington, DC, 2010. (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w165.pdf)
4. Azari, H., N. Kringos, and T. Scarpas. *NCHRP Web-Only Document 166: Precision Estimates of AASHTO T 283: Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage.* TRB, The National Academies, Washington, DC, 2010. (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w166.pdf)

TRB

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

ISBN 978-0-309-15526-7

Subscriber Categories: Highways • Materials

These digests are issued in order to increase awareness of research results emanating from projects in the Cooperative Research Programs (CRP). Persons wanting to pursue the project subject matter in greater depth should contact the CRP Staff, Transportation Research Board of the National Academies, 500 Fifth Street, NW, Washington, DC 20001.